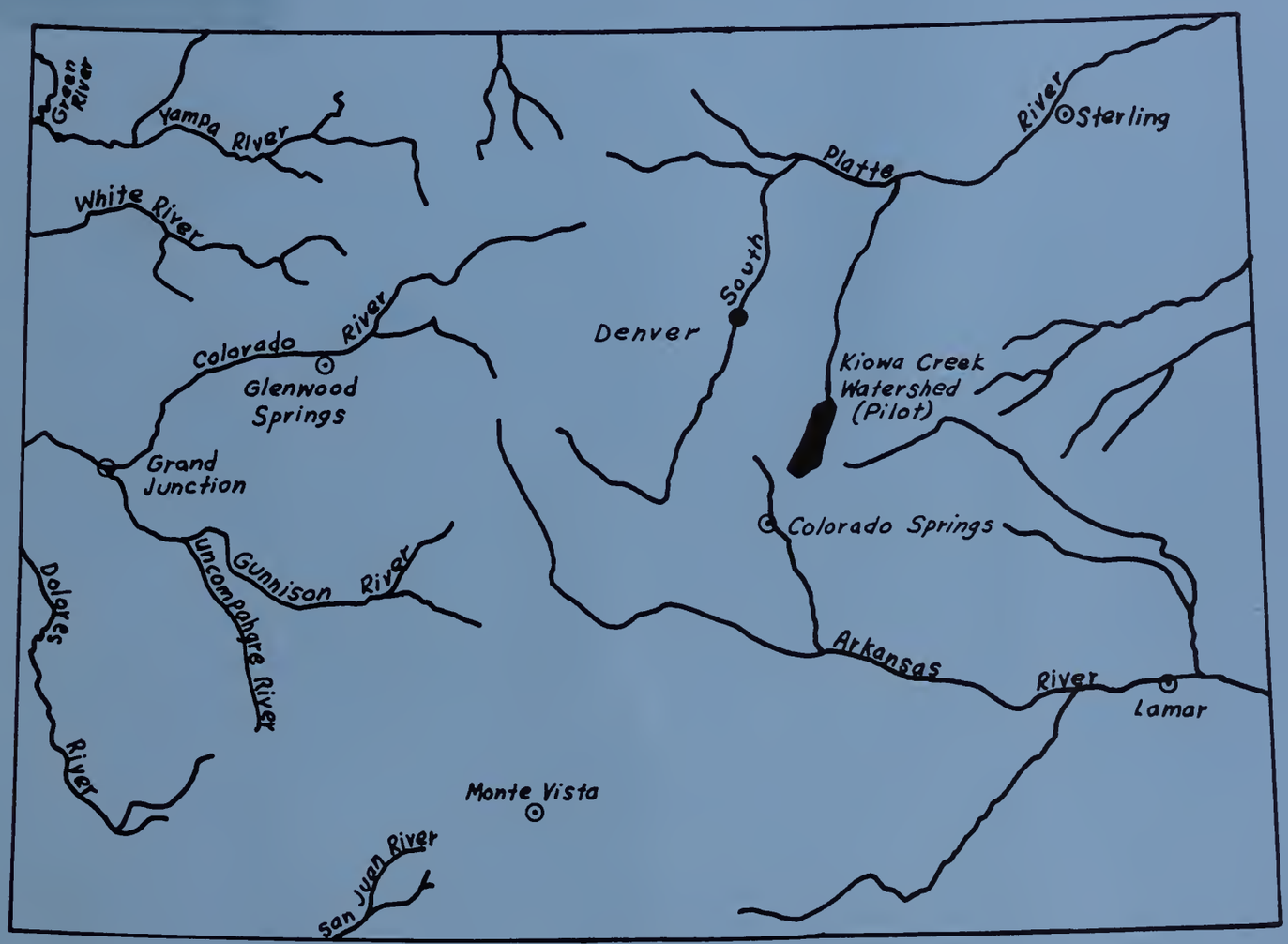
WATERSHED PROGRAM EVALUATION

KIOWA CREEK WATERSHED, COLORADO



PREPARED BY
SOIL CONSERVATION SERVICE ECONOMIC RESEARCH SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

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FOREWORD

The Kiowa Creek Watershed Protection Project was completed in June of 1961. It was installed under the authority of the Soil Conservation Act of 1935 (Public Law 46, 74th Congress) as implemented by the watershed protection item in the United States Department of Agriculture Appropriation Act of 1954. Pilot watershed projects were initiated in 62 small upstream areas, seven of which were later deauthorized at the request of local sponsors. These pilot projects were installed to demonstrate the benefits of watershed treatment in preventing damage from floods and sedimentation.

The Kiowa Pilot Project was one of ten selected for intensive evaluation of results. The broad objective of these evaluations was to measure the effectiveness of the applied programs in both physical and economic terms. Studies were made as to benefits resulting from:

1. Reduction of floodwater and sediment damages.

2. Changes in runoff characteristics.

3. Changes in crop and forage production.

4. Changes in the economy of the area.

This report describes the studies undertaken and sets forth the findings for the period September 1954 through December 1965.

A work plan for the Kiowa Creek Watershed Protection Project was developed in 1954, including a supplement for program evaluation. This plan was further developed and amended in 1956 and 1958.

People in the project area had been interested in soil conservation and flood control for many years. In June 1941, the Kiowa Soil Conservation District, sponsor of this pilot project, declared in its work plan: "The purposes for which this district is organized are to control floods and erosion, and to develop and establish a general system of soil conservation and improved land use practices."

This report is the result of joint efforts of the Soil Conservation Service, the Natural Resource Economics Division of the Economic Research Service, the Water Resources Division of the U. S. Geological Survey, and the U. S. Weather Bureau. Additional information or details of the evaluations may be obtained from the respective agencies participating in evaluation studies. In some cases separate reports have been prepared on detailed investigations.

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SUMMARY

The Kiowa Creek Watershed Project (75,520 acres) includes the drainage area above the town of Kiowa, Colorado. Erosion, floodwater and sediment damages are major problems in the watershed area, which is subject to rainstorms of high intensity and short duration. The economy of the area depends almost entirely on agriculture, although there is a trend toward off-farm employment to increase family income. Livestock production is the predominant agricultural enterprise. About 80 percent of the agricultural area is used for pasture or rangeland.

To reduce floodwater and sediment damages in the watershed, a total of 60 floodwater-retarding structures, 9 grade-stabilization structures, and 12,292 feet of channel improvement were installed at a cost of $597,079. As of June 1961, land treatment measures costing $183,687 had been installed for a total investment in works of improvement amounting to $780,766. The number of structural and land treatment measures installed for flood prevention, land stabilization, and sediment control is smaller than estimated in the initial project plan, but subsequent flood events have shown that the installed program performs satisfactorily the functions for which it was designed.

During the evaluation period, average annual total precipitation ranged from over 18 inches to less than 14 inches for individual stations. Comparison of records with nearby stations indicated that precipitation during the evaluation period was essentially normal. In the storm of June 17, 1965, precipitation amounts of over seven inches were recorded at the southeastern edge of the watershed.

Two major flood events occurred during the evaluation period. One, that of July 30, 1957, affected only a small part of the area; the other, on June 17, 1965, affected most of the area. On July 30, 1957, the peak inflow to K-79 Reservoir was 5,250 cubic feet per second; reservoir storage reduced this to a peak outflow of 1,480 c.f.s. The inflow was much greater than the 50-year frequency flood; the outflow was much less. Peak inflow rates for the flood of June 17, 1965, at K-79, J-33, R-3, and Q-51 all were greatly in excess of the 50-year frequency flood. Structures K-79 and R-3 reduced these inflows of substantially greater than a 50-year flood to outflows of substantially less than the 50-year frequency period. On the other hand, peak reduction at Q-51 was almost negligible.

The peak discharge of the June 17, 1965, flood on East Kiowa Creek above Elbert was 41,500 cubic feet per second, almost as great as the May 1935 peak of 43,500 c.f.s. on Kiowa Creek at Elbert. West Kiowa Creek produced a peak of 20,000 c.f.s. in 1965. This peak was slightly behind the peak on East Kiowa, but the peak on Main Kiowa Creek at Elbert is estimated to have been about 45,000 c.f.s. from the addition of the two flows. For without project conditions it is estimated that a peak discharge of 66,000 c.f.s. would have occurred on Main Kiowa Creek at Elbert.

Sediment discharge has been much greater and more frequent on Kiowa Creek at Kiowa than at East Kiowa Creek and West Kiowa Creek at Elbert. Most of the sediment discharge at each site occurs during a few days each year in large flows. A general reduction in fine sediment has occurred during the evaluation period. This may be correlated with the establishment of conservation measures and general improvement of vegetative conditions in the watershed.

Channel profile and cross section studies show that the profile slope for each stream did not change appreciably between 1956 and 1965, that there was a tendency toward widening of the channel, and that only minor aggradation or degradation occurred at the different sections.

Reservoir sedimentation surveys showed a wide range in rates of sedimentation. The average sedimentation rate for the five reservoirs studied, 0.25 acre-foot per square mile per year, is slightly below the expected average rate. The average annual capacity losses of allotted sediment pool storage at the five reservoirs is 1.84 percent or slightly less than the planned rate of 2 percent.

Range evaluation studies indicated that the native range plant cover is improving and improvement under controlled grazing use almost equals that in test plots under complete protection from livestock.

Economic surveys indicated a trend towards less intensive land use in the watershed as a whole. During the evaluation period there was a reduction of cropland of approximately 1,800 acres, most of which was planted to permanent pasture. There was also a large reduction in the number of dairy and cash crop farms. By 1965, almost 75 percent of the operators reported livestock as the main source of farm income.

Flood plain land use showed a trend toward increased feed and forage production for the range livestock industry of the watershed. Benefits from more intensive use of flood plain lands were not as great as estimated in the work plan, but there was a definite trend toward more intensive use.

Flood damages amounted to only $6,565 during the 1955-64 period. However, the storm of June 17, 1965, which exceeded the design storm, caused damages of $169,165 within the watershed area. During the 10-year period (1955-64) the comprehensive system of land treatment and structural measures resulted in estimated flood prevention benefits of $31,570. Flood damage reduction benefits from project measures were estimated to be $100,105 during the 1965 storm. Total benefits from reduction of flood damages were estimated to be $131,675 for the 1955-65 evaluation period. Average annual damage prevention benefits for this period amounted to $11,971.

Experience gained from this study indicates weaknesses in study techniques for evaluation of benefits of specific items in the land treatment or structural program. This is particularly true when floods exceed the capacity of the floodwater-retarding structures by several times. It is also evident that short-term evaluation studies do not provide an accurate means of checking estimated long-term benefits resulting from installing watershed works of improvement.

WATERSHED PROGRAM EVALUATION - KIOWA CREEK WATERSHED, COLORADO 1/

Soil Conservation Service and Economic Research Service

WATERSHED CHARACTERISTICS

Kiowa Creek is tributary to the South Platte River at a point approximately 15 miles west of Fort Morgan, Colorado. The 75,520 acres in the watershed project include only the drainage area above the town of Kiowa, Colorado. The watershed is about 26 miles long and on the average about 5 miles wide. Kiowa Creek has its headwaters in the Black Forest area of El Paso County, about 20 miles northeast of Colorado Springs. The headwaters area is partly timbered, rolling to rough upland broken by numerous drainageways. This area is drained by two main tributaries, East Kiowa Creek and West Kiowa Creek, which join at Elbert, Colorado, to form the main Kiowa Creek. 2/ Average fall of the main channel is about 50 feet per mile, and side drainages fall from 100 to 200 feet per mile. Altitudes range from about 7,700 feet at the headwaters of West Kiowa Creek to about 6,350 feet at Kiowa, Colorado.

Farming or servicing farm activities are the primary occupations within the watershed area. The small towns of Elbert and Kiowa, with a combined population of 500 people, provide local marketing facilities. State Highway 86 runs east and west through Kiowa, and State Highway 157 runs south from Kiowa through the project area. Together with a network of county roads, they provide an adequate transportation system. There are no railroads in the watershed area; a branchline of the Colorado and Southern Railway was abandoned after being severely damaged by the major flood of 1935.

Soils of the watershed are generally sandy to medium textured. They are developed principally on materials derived from the Dawson Formation, with small areas in the higher reaches developed on the Castle Rock Conglomerate. Soils are shallow in the headwaters area and become deeper downstream. Most of the cultivated soils have a medium-textured topsoil with moderate permeability and depths of 20 to 36 inches. Flood plain soil that has not been damaged by floods is fertile and easily tilled. Precipitation records were kept by the Kiowa State Bank from 1920 through 1959. Average annual rainfall based on this 40-year record is 16.2 inches. Most precipitation comes in the form of rain from April through August. The frost-free growing season varies with elevation and averages about 123 days. Late spring frosts are not uncommon.

1/ This report is the result of joint efforts of the Soil Conservation Service, the Natural Resource Economics Division of the Economic Research Service, the Water Resources Division of the U. S. Geological Survey, and the U. S. Weather Bureau.

2/ U. S. Geological Survey maps and publications use the name Kiowa Creek for the stream reach designated East Kiowa Creek in this report.

Watershed Problems

Erosion, floodwater, and sediment damages are major problems in the Kiowa Creek Watershed. The watershed is subject to rainstorms of high intensity and short duration. This type of storm on steep slopes produces flash floods with comparatively small volumes of water. Erosion is a critical problem on the Class VI lands that are under cultivation. Farming such land has resulted in both sheet and gully erosion. Gullies often extend through the cropland and into the range and forested areas. Sediment produced by these areas causes considerable flood plain damage from deposition of silt, sand, and other materials carried by floodwaters. This sediment, which is composed mainly of infertile sand, is deposited on the flood plain in depths that range from a few inches to 6 feet. Runoff from high-intensity rains causes streambank erosion in some areas and sediment deposition in others.

Other major problems stemming from improper land and water management practices occur in the form of damages to roads, bridges, fences, and other developments in the flood plain areas.

Major floods are known to have occurred in this watershed area on May 21, 1878, and May 30, 1935. Other floods occurring before the installation of the watershed project were in 1920, 1921, 1925, 1933, and 1945. The most destructive was the flood of 1935. This flood took seven lives and caused property damage of more than two million dollars including the abandonment of the branchline of the Colorado and Southern Railway which ran through about two-thirds the length of the watershed. Extensive flood damages to railroad bridges and tracks made it uneconomical to resume operations. An appraisal of annual damages was made in 1954 for project formulation. It was estimated that annual flood damage averaged $49,550, not including the 1935 railroad damage. Indirect losses to businesses and interruption of travel were estimated at $4,950, making total average annual damages of $54,500.

Preproject average annual flood damages as estimated in 1954 were as follows:

Type of Damage	Dollars
Floodwater	
Crop and pasture	3,390
Flood plain scour	4,320
Channel scour	15,710
Other agricultural	7,500
Roads and bridges	5,580
Subtotal	36,500
Sediment	
Flood plain deposition	13,050
Indirect	4,950
Total average annual damage	54,500

Preproject Conservation Application

A Civilian Conservation Corps camp was established within the project area following the disastrous flood of 1935. Considerable work, such as contour furrowing, building stockwater dams, gully control structures, and diversions, was accomplished before the camp was closed in 1942. Also, as a result of the 1935 flood, the Corps of Engineers, U. S. Army, constructed rock and earth dikes to protect the towns of Elbert and Kiowa from flood damage. The Kiowa Soil Conservation District, organized in 1941 with flood control as one of the main features of its program, made considerable progress in applying land treatment measures before development of the watershed work plan in 1954. A total of 3,210 acres of pasture and rangeland had been seeded, 7,260 acres had been contour furrowed, 100 erosion control structures had been built, 98 ponds, 5 miles of terraces, 5 miles of diversions, 30 acres of waterways had been developed, and 1,000 acres of contour farming, stubble mulching, or strip cropping had been initiated prior to 1954. These measures alleviated a portion of the floodwater, sediment, and erosion damages within the watershed, but the local leaders recognized that a concentrated program of floodwater and sediment control structures and land treatment would be necessary to provide adequate protection from flash floods.

Water Use and Sources

There are 27 irrigation water filings on the entire Kiowa Creek drainage, claiming 700 cubic feet per second of direct flow. Of this flow, only 31 cubic feet per second is within the project area. Since the flood of 1935, use from these filings has been limited. Channel changes have made it difficult and even impossible at times to maintain diversion structures and main ditches. Irrigators report that in the Kiowa Valley below the project area, sediment carried by floodwater is detrimental to irrigation because it seals and crusts the soil surface.

The first irrigation well in the project area was drilled in 1940, and seven additional wells were drilled from 1947 to 1953. In 1954, these wells had an estimated capacity of 100 to 500 gallons per minute. About 400 acres were irrigated from pumps.

Municipal wells provide water for domestic use in the town of Kiowa. Individual wells provide domestic water in the town of Elbert as well as for farm and ranch headquarters. Livestock water is obtained from both wells and farm ponds.

Watershed Economy

The economy of the area depends almost entirely on agriculture, although there is an increasing trend toward farmers working part time in nonagricultural pursuits. The proximity of Colorado Springs, the Air Force Academy, and Denver provides opportunities for off-farm employment. Also, the upper portion of West Kiowa Creek is being developed as residential sites for urban workers.

Livestock production always has been the predominant agricultural enterprise in the watershed with 75 percent of the farms having livestock production as the major enterprise. Over 80 percent of the area used for agricultural production remains in pasture or rangeland and most of the cropland is devoted to raising feed for livestock. About half of the units are ranches of over 1,000 acres.

A significant factor in the economy of the area is the sale of ranches for residential developments or recreational uses. Since these buyers are willing to pay a significantly higher price for desirable woodland sites than their value as rangeland, the market value of this land has been affected. This increased land value has benefited a few local operators who had land for sale, but the higher prices have made it nearly impossible for small ranchers to expand their operations.

Perhaps the best example of this change in land use is the 2,600 acre Peaceful Valley Scout Ranch purchased by the Boy Scouts of America in December 1961. An estimated 2,026 acres of wooded and upland grasslands is being developed into camp areas and headquarters for scout activities. This acreage was formerly pastured and was mostly wooded grassland. The bottomland crop and pastureland is presently leased to local farm operators. After a 20-year development period, the camp will have six major camp areas, each of which will contain 12 to 14 troop sites. In addition, there will be administrative facilities, a lake, and a swimming pool. These developments will enable more than 1,200 campers to use the facilities at one time. The Boy Scouts of America estimate present value of the ranch and developments at over $1,000,000. With the planned 20-year building program, final investment will be over $5,000,000. Also included in the watershed area is the Jewish Community Center (J-CC Ranch), with approximately 400 acres of land. The J-CC Ranch is operated as a summer camp for children, with facilities for 125 children at one time. Both of these camps are cooperators with the Kiowa Soil Conservation District and have an active program to reduce runoff and erosion on their lands.

Since 1960, a considerable acreage of land has been subdivided into residential building sites in the upper end of West Kiowa Creek. At the end of the project evaluation period (December 1965), approximately 3 square miles of land were being subdivided or had been sold as residential sites. Most of these lots are being purchased as homesites by people working in Colorado Springs (a distance of about 15 miles) or by employees of the Air Force Academy (a distance of 8 miles). This use of land will continue to grow and could materially increase runoff and erosion from this portion of the watershed area. The Kiowa Soil Conservation District will need to make a special effort to assist these new owners with their conservation problems and to acquaint them with the assistance available for accomplishing conservation measures.

PROGRAM OF IMPROVEMENT

Planned Program

The plan for watershed improvement formulated in September 1954 and revised in January 1956 by the Soil Conservation Service and the local sponsor contains recommendations for two general groups of conservation measures: "A Measures", consisting of flood-prevention and grade-stabilization structures, and "B Measures", consisting of land treatment for conservation of water and watershed lands. Works of improvement in the A group were to be installed primarily with Federal project funds, while those in the B group were to be paid for by farmers with financial assistance from other national programs. Table 1 lists amounts of the respective A and B Measures included in the work plan September 1954, those included in the revised plan of January 1956 and the revised estimate of June 1958, and those installed as of June 1961 and December 1965.

Floodwater-retarding and erosion-control structures (A Measures) were planned to control runoff from approximately 65 percent of the watershed. These structures were to be earth fill with reinforced concrete pipe outlets. Stabilization and sediment control structures were planned to arrest gully development, stabilize waterways, and reduce sediment damages.

The Soil Conservation Service and the project sponsor agreed that the structural program (A Measures) would include a number of small floodwater-retarding structures, with small sediment control structures above many of them, and a limited amount of channel improvement work along the main stem of Kiowa Creek. This approach appealed to the local people because it spread the benefits to a greater number of individual farms. After the project had been under construction for approximately 1 year, it became evident that certain structural sites could be eliminated and others could be enlarged, modified, or the location slightly changed and still accomplish the original objectives and desired degree of protection.

Estimated quantities of B Measures needed in the project area were developed by use of technical guides based on conservation surveys. Land treatment measures included such practices as seeding cultivated and abandoned cropland to grass, grass management, furrowing or pitting rangeland, constructing small erosion control and stockwater dams, and terracing, stubble mulching, strip cropping, and contour farming on cropland. On the ponderosa pine timberland, woodland management measures were included.

The original plan was amended by local landowners and Soil Conservation Service planning technicians assisting the sponsor. This amended work plan dated January 1, 1956, reduced the number of floodwater-retarding structures from the originally planned 140 to 68, provided for technical assistance for land treatment, and included a revised supplement covering the project evaluation program. In 1958 the estimates of needed land treatment measures were reexamined, deemed in excess of actual needs, and revised. The revised estimate of land treatment needs (subsequent to 1954) is shown in Table 1.

Table 1. Works of improvement recommended, September 1954, as revised January 1956 and June 1958, and as installed June 1961 and December 1965, Kiowa Creek Watershed, Colorado

Watershed Improvement Measures	Unit	Original Work Plan Sept. 1954	Revised Work Plan Jan. 1956	Revised Estimate June 1958	Installed as of June 1961	Installed as of December 31, 1965
A Measures:						
Floodwater-retarding structures	No.	140	68	68	60	60
Grade stabilization structures	No.	25	50	50	9	9
Channel improvement	L.F.	25,000	25,000	25,000	12,292	12,292
B Measures:						
Pasture and range seeding	Ac.	9,790	9,790	5,900	3,800	4,974
Contour furrowing	Ac.	7,740	7,740	4,740	1,121	1,181
Erosion control structures	No.	1,150	1,150	185	25	25
Pond construction	No.	35	35	35	37	47
Range improvement	Ac.	70,000	70,000	58,000	47,829	48,000
Woodland management	Ac.	10,000	10,000	10,000	4,806	4,846
Fencing	Mi.	75	75	25	11	11
Terraces	Mi.	60	60	50	12	12
Field diversions	Mi.	60	60	60	30	36
Waterway development	Ac.	470	470	170	34	34
Contour farming	Ac.	(	4,000	2,000	395	1,261
Stubble mulching	Ac.	(4,000	3,000	1,000	506	600
Strip cropping	Ac.	(	1,000	500	0	130
Land reclamation	Ac.				186	353
Improved water application	Ac.				527	536

Structure F-18 near the Elbert - El Paso County Line in the East Kiowa Creek drainage. 10-5834-11

Structure Q-51; recording gauge, baffle, and part of dam. 10-4091-8

The estimated installation costs of original and revised programs of improvement and the costs of measures actually installed, itemized by type of measure, are given in Table 2. These estimated costs exclude the expenses of developing the work plan and project evaluation.

Estimated Benefits

Listed below are the average annual benefits that were expected to result from the revised program of watershed improvement (January 1956):

Reduction of floodwater damage	$ 26,730
Reduction of sediment damage	11,570
Reduction of indirect floodwater and sediment damage	3,830
More intensive use of flood plain lands	21,980
Total annual flood prevention benefits	$ 64,110

It was estimated that the planned land treatment measures, together with the structures for retarding floodwaters and controlling sedimentation, would reduce average annual damages by $42,130 or approximately 77 percent. This is a reduction from $54,500 without the project to $12,370 with the project. In addition, benefits from intensifying land use on flood plains were expected to be $21,980, making total benefits of $64,110. It was estimated that conservation benefits to landowners and operators in the upland area would amount to $46,960 annually.

Installed Program

When the project was authorized in 1954, there were 101 farm and ranch units wholly or partially in the project area. Thirty-four, or about one-third, had cooperative agreements and basic plans with the Kiowa Soil Conservation District, covering 31,906 acres or about 42 percent of the project area. By June 1961, the number of operating units had decreased to 99 with 85 having district agreements on 71,955 acres or 95 percent of the project area and 74 having basic conservation plans covering 63,308 acres or 83 percent of the project area.

The works of improvement installed in the Kiowa Creek Watershed Project area as of June 1961 are listed in Table 1. Table 2 lists the costs of these measures as installed. In the A group of measures, 60 of the 68 planned floodwater-retarding structures were installed. Detention pool storage capacity of the installed structures totaled about 2,600 acre-feet, in contrast to 2,676 acre-feet planned. These structures were designed to contain the runoff from storms with recurrence intervals of 25 years or less and to regulate runoff from storms with recurrence intervals of more than 25 years. This regulation extends over 70.9 square miles or 60 percent of the total drainage area in the watershed. In addition to the 69 structures listed above, the project includes one small unnamed floodwater-retarding structure constructed by the District cooperators.

Table 2. Estimated costs, September 1954, as revised January 1956, and incurred as of June 1961, Kiowa Creek Watershed, Colorado

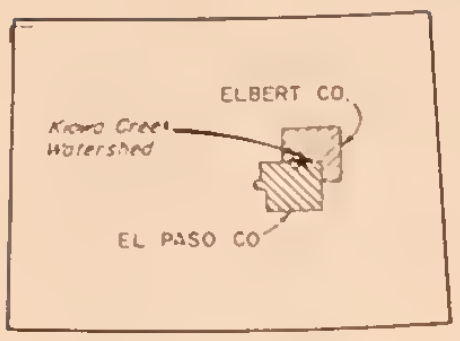
Measures Recommended	Estimated Cost		Actual Cost
	Original Work Plan Sept. 1954	Revised Work Plan Jan. 1956	Installed Measures June 1961
	Dollars	Dollars	Dollars
A Measures:			
Floodwater-retarding structures	555,044	710,544	554,983
Grade stabilization structures	47,080	46,080	28,821
Channel improvement	20,820	20,820	13,275
Total A Measures	622,944	777,444	597,079
B Measures:			
Pasture and range seeding	146,900	146,900	57,000
Contour furrowing	15,500	15,500	2,242
Erosion control structures	17,300	17,300	2,875
Pond construction	14,000	14,000	14,800
Range improvement	77,000	77,000	71,744
Woodland management	20,000	20,000	9,612
Fencing	30,000	30,000	6,050
Terraces	6,000	6,000	2,400
Field diversions	24,000	24,000	12,000
Waterway development	14,100	14,100	1,360
Contour farming		4,000	1,580
Stubble mulching	8,000	3,000	2,024
Strip cropping		1,000	
Total B Measures	372,800 1/	372,800 1/	183,687 2/
Estimated total project costs 3/	995,744	1,150,244	780,766

1/ Includes $51,570 anticipated ACP payment.
2/ Excluding the cost of SCS and FS technical assistance ($43,266).
3/ Excluding the cost of installation services, developing the work plan and of project evaluation.

In general, quantities of B Measures installed are fewer than those listed as needed in 1954. There are several reasons for this, but probably the most important is the unfavorable cost-price relationship under which farmers have been operating since the project's inception. Also, the land treatment phase of the program was seriously delayed because of two drought periods. Farmers were unable to spend money for conservation work when the chance for financial return was small and funds were urgently needed for living expenses.

The greatest progress in applying land treatment measures has been made in range management and pasture and range seeding practices. Although there is still much to be accomplished in each practice, progress is good when considered in light of the number of small farm units in the area. It will be difficult, if not impossible, to get complete conservation on farms that cannot adequately support a family and on which farming would continue to be uneconomical even if all needed conservation practices were carried out. The trend toward residential farms has also delayed application of needed land treatment measures, because most of these people are not acquainted with the particular land management problems of the area. The Kiowa Soil Conservation District is planning to make a special effort to assist these small tract owners with their conservation problems.

The total cost of the installed program of improvement was $780,766, of which $597,079 was for A Measures and $183,687 was for B Measures. These costs are approximately 23 percent less and 51 percent less, respectively, than the cost estimates of the revised plan (January 1956). Available information indicates that the original work plan over-estimated the land treatment needs of the watershed. The revised estimate of June 1958 reduced estimated land treatment needs, but even these lower estimated amounts of land treatment measures were not installed during the project installation period. Some needed land treatment measures were not installed at the end of the project evaluation period in December 1965.



LOCATION MAP

LEGEND

- Watershed Boundary
- County Line
- Drainage Area Controlled by Structure
- Sample Evaluation Area
- Floodwater Retarding Structure
- Stream Gauge
- Rain Gauge

KIOWA CREEK WATERSHED

ELBERT AND EL PASO COUNTIES, COLORADO

SEPTEMBER 1966

SCALE IN MILES

PROGRAM EVALUATION

Objectives

The Kiowa Creek Watershed evaluation plan was included as a part of the original work plan in 1954. The primary objective was to evaluate the effects of the watershed protection program in physical and economic terms. A further objective was that results of this and similar evaluations would provide a sound basis for improvement in planning and installing watershed projects carried out under P. L. 566.

The original evaluation plan was amended in 1956 to provide for the additional equipment and instrumentation needed to ensure proper measurement of annual benefits. Provision was made for an additional stream flow gage and sediment load station in 1962.

Evaluation studies were conducted from 1955 through June 1966 to measure various physical and economic factors within the watershed and changes brought about by the program. These factors include changes in runoff characteristics, flood and sediment damages, and crop and forage production resulting from improvement in soil and moisture conditions. The specific objective of the evaluation studies was to measure the effectiveness of the works of improvement.

A detailed inventory of basic data was compiled in 1962. 1/ This report contains as-built features of all floodwater-retarding structures, monumented range locations and grid surveys in five reservoirs and data on 25 monumented cross sections. The report brings together into one document available basic data and location of instrumentation as of June 30, 1961. It contains data supplemental to that contained herein.

Hydrologic Instrumentation

Precipitation Gages

Precipitation gages were installed by the U.S. Weather Bureau in December 1954 at 14 locations in the upper Kiowa Creek Watershed. These included 10 standard 8-inch gages and 4 recording gages. Observers were local resident volunteers. Processing and publication of the records from these stations were taken over by the Weather Bureau in January 1956. Records of the standard gage stations were published in "Climatological Data, Colorado," and of the recording gage stations in "Hourly Precipitation Data, Colorado." The Weather Bureau provided regular inspection and maintenance of the stations. The network of stations was continued in operation through 1965. Some of the gages were relocated, but seven of the stations, including three of the recording gages, remained at the original location and have essentially complete records for the period January 1955 through December 1965. Other stations were relocated one or two times during the period; two of these have essentially complete records for the 11-year period, and the remaining five have records complete for 8 to 10 years.

1/ DANSDILL, F. C., INVENTORY OF BASIC DATA FOR PILOT WATERSHED PROGRAM EVALUATION, KIOWA CREEK WATERSHED. U. S. Department of Agriculture, Soil Conservation Service, 1962.

Aerial photo of two floodwater dams after a storm in 1963. 10-9008-7

Outflow tube of structure 2 G-10 operating after storm in 1963. 10-9007-10

Results

Annual precipitation at project stations ranged from about 20 inches to more than 27 inches in the wettest years and from less than 7 inches to more than 11 inches in the driest years. Average annual totals at individual stations ranged from over 18 inches to less than 14 inches for the period 1955 through 1965. The precipitation pattern shows a general increase with elevation, but this appears to be strongly modified by local exposure factors and the high variability of precipitation in the area from year to year and from place to place.

The wettest year for most stations in the project area was 1957, with 1965 a close second. Other wet years were 1958 and 1961. The driest year was 1964, followed by 1956 and 1962. Ayer Ranch, located just south of the project area at an elevation of 7,232 feet, recorded the wettest year since 1944 in 1957 and the driest in 1964. Records made since 1911 in or near Monument, Colorado, which is located west of the project area, and is the nearest long-record station in a somewhat similar region also shows the wettest year in 1957. The driest year at Monument during the project period was 1955; drier years were recorded there in 1934, 1939, and 1954.

An average of about 60 percent of the annual precipitation occurs during the months of May through August, and 75 to 80 percent during the 6-month period of April through September. Most of the project stations commonly recorded a total of 1 inch or more for each month during the period May through August. Less than 1 inch has occurred in one or two of these months in very dry years. In most years at least 2 months have precipitation of 2 inches or more. Monthly totals for May through August range from low values around 0.25 inch at several stations to over 12 inches at a station near Eastonville in June 1965. Heavy precipitation occurs less frequently in April or September. In April, the heavier amounts are usually in the form of snow.

Comparison of the project period precipitation records with longer period records at nearby stations shows no significant indication that the project period was either drier or wetter than might be expected. In most cases, precipitation averages for the project period were a little higher than for earlier periods. Indications of a wetter period for the 10 years through 1964 may be discounted somewhat by the consideration that the 30-year "normal" values are in general somewhat lower than would be obtained over a longer period, since two drought periods are included.

In summary, the records from longer period stations near the project area give no indication that precipitation during the project period varied significantly from the long-term expectancy. Frequency of higher short-period rates of precipitation may have been a little less during the project period through 1964, excepting 1965 when some of the highest rates on record were recorded.

June 1965 Precipitation

The highest recorded precipitation rates in the project area occurred at stations in the upper portion of the watershed on June 17, 1965. Variations in daily totals over the area are shown in Table 3. Daily totals from official and unofficial reports ranged from less than one inch at the northern edge of the project area to over seven inches at the southeastern edge. A number of unofficial reports indicate daily totals of 8 to 12 inches or more just across the divide southeast of the Kiowa Creek Watershed and similar amounts in an area about a mile south of the divide. Amounts were much less to the west, with some stations across the Douglas County line reporting less than half an inch. The only indication of similar high rates in the records for the area is from a single observation near the head of Kiowa Creek, that reported 24 inches in 24 hours late in May 1935.

Table 3. Precipitation at official Weather Bureau stations for June 17, 1965, Kiowa Creek Watershed, Colorado

Station	Total Inches	Remarks
Ayer Ranch 1/	6.66	Total fell in 10 hours
Eastonville 1 NNW 2/	7.10	6.4" fell in 4 hours
Eastonville 2 NNE	7.60	
Eastonville 3 NW	4.65	
Eastonville 6 WSW	1.98	2.25" fell on 15th and 16th
Elbert	3.10	
Elbert 3 NW	2.12	1.05" fell in 5 hours
Elbert 3 SE	4.00	Most fell in 2 hours
Elbert 5 SW	3.22	
Elbert 6 SSE	4.92	
Elbert 8 SW	3.68	
Kiowa 1 W	.90	
Kiowa 4 SW	1.52	
Kiowa 5 S	2.66	
Kiowa 5 SE	3.80	

1/ Not in Kiowa Creek Watershed.
2/ Figures and letters following the station name indicate distance in miles and direction from the post office.

Records at Gaging Stations

Beginning in 1955, reservoir stage and streamflow records were collected on Kiowa Creek and its subwatersheds in the study area (see Table 4 and 5).

Table 4. Reservoir gages in project area, Kiowa Creek Watershed, Colorado

Subwatershed and Location	Drainage Area (Square Miles)	Date Established
K-79 Reservoir, near Eastonville	3.20	July 20, 1955
J-33 near Eastonville	1.12	June 6, 1956
R-3 near Elbert	2.82	June 20, 1956
Q-51 near Elbert	0.59	April 17, 1957
B-9 near Elbert	0.64	November 28, 1955

Table 5. Streamflow stations in project area, Kiowa Creek Watershed, Colorado

Stream and Location	Drainage Area (Square Miles)	Date Established
East Kiowa Creek at Elbert	28.6	May 3, 1955
West Kiowa Creek at Elbert	35.9	July 23, 1962
Kiowa Creek at Kiowa	111.0	November 28, 1955

The reservoir gages were equipped with continuous water-stage recorders and tipping-bucket rain gages. The time scale of the strip chart on which both water stage and precipitation amounts are recorded was 9.6 inches per day, rather than the usual 2.4 inches per day, in order to facilitate the computation of inflow rates using rate of change in reservoir contents, precipitation amounts, and outflow rates. Outflow rates were determined from relations between reservoir stage and spillway discharges. Relations between stage and discharge for the principal spillways were defined by current-meter measurements, Parshall flume ratings (at B-9, Q-51, and J-33 only), orifice formulas, and flow-through-culvert computations. The stage-discharge relations for the emergency spillways, except at B-9, were determined by indirect measurement of peak discharge and stage-conveyance relations. No flow occurred through the emergency spillway at B-9 during the project period. Records were not collected during the winter months.

The three streamflow stations were equipped with continuous waterstage recorders, and their stage-discharge relations were based on current-meter measurements and indirect measurements of peak discharge. Records for winter months were based on occasional current-meter measurements and temperature records.

During most of the period, there was no, or negligible, flow at the reservoir stations, but two major flood events did occur. The flood of July 30, 1957, on East Kiowa Creek at K-79 Reservoir is discussed by Jenkins 1/, as an example of an outstanding flood that possibly would have been unnoticed except for the K-79 gage. The flood of June 17, 1965, most certainly would not have gone unnoticed. In Water-Supply Paper 1798-A, Jenkins 1/ suggested that the relation between magnitudes of floods of given recurrence intervals frequently can be expressed in the form of the empirical equation $Q = C(A)^x$, where Q is the peak discharge, in cubic feet per second, of the flood of the given recurrence interval; C is a measure of the recurrence interval of the discharge Q; A is the size of contributing drainage basin, in square miles; and x is an exponent. He suggested that the value of the exponent x usually ranges between 0.6 and 0.8 and based his comparison between the 1957 flood at K-79 and the May 1935 flood at two points on Kiowa Creek on the assumption that the value of x for the Kiowa Creek basin was 0.7. However, a recent regional analysis of the Platte River basin shows the value of x in the area that includes the upper Kiowa Creek basin to be 0.47. The regional analysis gives a value of C for the 50-year flood of 1,820 in the equation $Q_{50} = C_{50}(A)^{0.47}$. Values of C, using the exponent 0.47, are shown in Table 6 for the 1935 flood at two sites on Kiowa Creek, the 1957 flood at K-79, and the 1965 flood at the three gaging stations and at the five reservoir sites in the project area. Instrumental failures precluded computation of the 1965 peak inflow rates at two of the reservoir sites but they undoubtedly were substantially greater than the 50-year flood. The peak outflow rate at K-79 was more than 1-1/2 times as great as that in 1957, so it can be assumed that the peak inflow rate was at least as great as, and probably greater than, that of 1957, which was 1-2/3 times as great as the 50-year flood. The peak inflow rate for J-33 was at least equal to, and may have been considerably greater than, the peak outflow rate, which was 1-1/3 times as great as the 50-year flood.

The recurrence intervals of floods that have coefficients C greatly in excess of that for the 50-year flood cannot be estimated with even approximate reliability. Certainly, they are rare events. However, the differences between the coefficients for peak reservoir inflows and those for peak outflows may be worthy of note. Comparison of values of C shown in Table 6 indicates that the 1957 peak at K-79 and the 1965 peak at R-3 were reduced from inflows substantially greater than the 50-year flood to outflows substantially less than the 50-year flood. On the other hand, peak reduction at Q-51 was almost negligible. The flood at B-9 was not particularly outstanding, but the reduction in C value illustrates the degree of control on "moderate" floods exercised by the retardation structures.

1/ JENKINS, C. T. FLOODS ON KIOWA CREEK. In MUNDORFF, J. C. FLUVIAL SEDIMENT IN KIOWA CREEK BASIN, COLORADO. U. S. Geological Survey Water-Supply Paper 1798-A:A14-A19. 1964.

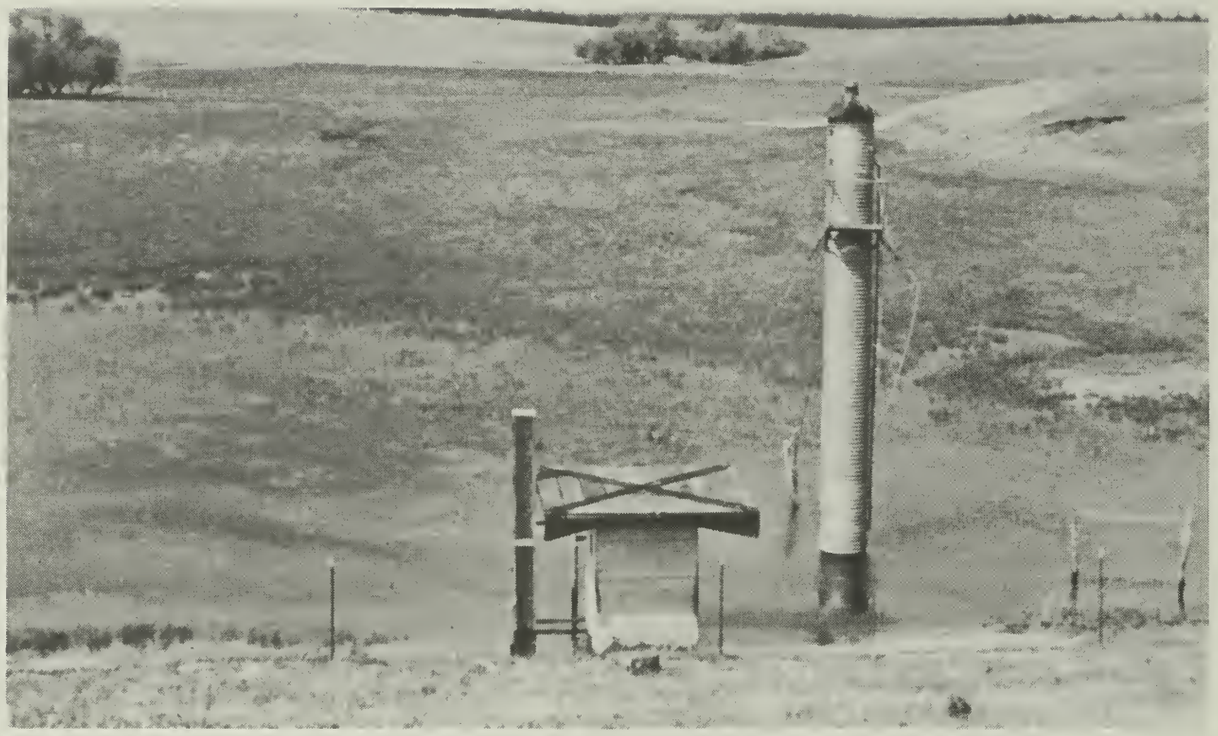
Table 6. Selected peak discharges in the Kiowa Creek Watershed, Colorado

Location	Drainage Area (Square Miles)	Date of Flood	Peak Discharge (c.f.s.) 1/	C 2/
Inflow to K-79	3.20	1957	5,250	3,040
Inflow to K-79	3.20	1965	not determined	--
Outflow from K-79	3.20	1957	1,480	857
Outflow from K-79	3.20	1965	2,370	1,370
Inflow to J-33	1.12	1965	not determined	--
Outflow from J-33	1.12	1965	2,600	2,460
Inflow to R-3	2.82	1965	6,880	4,230
Outflow from R-3	2.82	1965	2,010	1,230
Inflow to Q-51	.59	1965	1,350	1,740
Outflow from Q-51	.59	1965	1,270	1,630
Inflow to B-9	.64	1965	597	736
Outflow from B-9	.64	1965	33.4	41
East Kiowa Creek at Elbert	28.6	1965	41,500	8,580
West Kiowa Creek at Elbert	35.9	1965	20,000	3,710
Kiowa Creek below Elbert	65 3/	1935	43,500	6,120
Kiowa Creek at Kiowa	111	1965	19,700	2,150
Kiowa Creek 21 miles below Elbert	190	1935	110,000	9,320

1/ Peaks shown for reservoir inflows are the average for the five-minute interval.

2/ C is a measure of the recurrence interval of the peak discharge Q. The values shown for C are those computed from the regional equation, $C = Q/(A)^{0.47}$. C for the 50-year flood is 1,820.

3/ Revised.



Drop inlet and water stage recorder at K-79 Reservoir near Eastonville, Colorado. C-1

K-79 Reservoir after the storm of July 17, 1965. C-2

Crest Gages

Twenty Columbus-type crest gages were installed at selected locations throughout the watershed to record maximum heights of peak streamflow. Most were installed on selected study reaches of Kiowa Creek. Others were placed above and below designated floodwater-retarding structures.

The Columbus-type gage consisted of 5 and 7 feet sections of 2-inch pipe mounted to posts with metal clamps. The bottom of the pipes were equipped with standard 2-inch caps, perforated with six 1/4-inch holes at 60 degrees to permit entry of water. A combination of charcoal, ground cork, and soap powder was placed in the gage to facilitate establishment of high water marks on the 1 inch x 2 inch wooden measuring staff fitted in the pipe.

Soon after installation it became evident that there were many operation and maintenance problems. It was difficult to establish a desirable gage base elevation. If the pipes were set flush with the creek bed, the inlet holes became clogged with sediment, and if set at higher elevations the smaller flows were not recorded. After several trials, it was determined that a height of 6 to 12 inches above the creek bed was the practical elevation. This eliminated recording of smaller flows, but in most instances these flows were insignificant and had little effect on the evaluation program. In spite of varying gage heights the inlet holes became clogged with silt and trash at all elevations. Stream bank high water marks were consistently higher than the gage marks.

During the July 1957 storm, the crest gage on the K-79 subwatershed near the head of East Kiowa Creek was dislodged and washed away by the high flows. It was attached to a 6 to 8-inch diameter post and set 4 feet deep, but was not able to withstand the impact of floating logs and debris at high velocities.

As a result of the expense involved, continual failures, and the lack of usable data from these gages, it was decided to eliminate them and rely on highwater marks to determine peak stages.

Ground-Water Observations

Eight irrigation wells were selected to evaluate the effect of project measures on ground-water levels in the project area. The water level in each well was measured annually in December.

The hydrographs are quite variable, ranging from little or no fluctuation of water level to large cyclic fluctuations. Many variables affect the water level at any well such as amount of precipitation in vicinity of the well, permeability of soil near the well, distance from Kiowa Creek, and amount of ground-water pumpage in the area. The annual measurement of water levels was not adequate to define the effect of the project measures on the ground-water levels in the project area.

The detention structures undoubtedly affected water levels in the immediate vicinity and for some distance down gradient. In the valley alluvium adjacent to stream reaches, where the magnitude of the flow has been decreased but the duration has been increased due to the upstream structures, water levels may have attained a slightly higher base level.

The chemical quality of the ground water can be classed as good to excellent for domestic and irrigation uses. In general, the water is a calcium bicarbonate type with the dissolved solids ranging from 100 to 350 parts per million (ppm).

Practically all of the water analyzed meets the standards set by the U. S. Public Health Service 1/ for drinking water. The water from one well had dissolved solids in excess of the recommended 500 ppm, and the water from another well had a nitrate content very close to the recommended limit of 45 ppm.

Sedimentation Studies

Fluvial Sediment

Data Collection

Sediment-discharge data were obtained from K-79 Reservoir near Eastonville, East Kiowa Creek at Elbert, and Kiowa Creek at Kiowa from April 1956 to December 1965, and from West Kiowa Creek at Elbert from July 1962 to December 1965.

When records of sediment discharge were first obtained in the basin, drainage from about 60 percent of the area upstream from East Kiowa Creek at Elbert was controlled by floodwater-retarding structures; drainage from about 3 to 7 percent of the area between Elbert and Kiowa was controlled by September 1956. Only the data obtained during 1956 at Kiowa Creek at Kiowa gave an indication of sediment discharge under preconstruction conditions. By December 1958, drainage from about 60 percent of the basin was controlled. Because an appreciable part of the sediment discharge of Kiowa Creek at Kiowa probably originated in the drainage area of West Kiowa Creek, a streamflow and sediment station was established on West Kiowa Creek at Elbert in July 1962. By 1962 drainage from about half of West Kiowa Creek basin was controlled by floodwater-retarding structures; therefore, data for this station also represent controlled conditions.

Streamflow at all the stations in the basin is intermittent. Periods of zero flow are common at all stations, particularly in the fall and winter. East Kiowa Creek at Elbert had the longest periods of zero flow. Only during spring runoff from March through May and after summer thunderstorms is flow appreciable at any of the stations.

1/ U. S. PUBLIC HEALTH SERVICE. DRINKING WATER STANDARDS, 1962. U. S. Public Health Service, Publication 956 : 61 p. 1962.

Outflow tube operating at K-79 Reservoir near Eastonville, Colorado, July 1965. D-1

Closeup of the outflow tube at K-79 Reservoir showing the automatic sediment sampling equipment. D-2

The most prevalent flow condition for the 1956-65 study period has been zero flow or flows of less than 10 cfs (Table 7). Most of the sediment discharge occurs when runoff exceeds 10 cfs. During 1956-65, flow occurred about 5 percent of the time at East Kiowa Creek at Elbert and 55 percent of the time at Kiowa Creek at Kiowa. For the shorter period of data collection at West Kiowa Creek at Elbert, flow occurred about 60 percent of the time. The daily mean discharge during 1956-65 exceeded 10 cfs only 12 days at East Kiowa Creek at Elbert but exceeded 10 cfs 141 days at Kiowa Creek at Kiowa.

Table 7. Frequency and type of flow that occurred at the several stream stations, Kiowa Creek Watershed, Colorado

Station	Days in Operation	Days of No Flow	Days When Daily Mean Flow Was Less Than or Equal to 10 cfs	Days When Daily Mean Flow Exceeded 10 cfs
K-79 Reservoir	3,653	2,108	1,539	6
East Kiowa Creek at Elbert	3,440	3,242	186	12
West Kiowa Creek at Elbert	1,126	368	752	6
Kiowa Creek at Kiowa	3,653	1,582	1,930	141

Suspended-Sediment Discharge

Table 8 summarizes the periods of significant runoff and sediment discharge at the four sediment stations during 1956-65. The data show that water and sediment discharge have been much greater and have occurred much more frequently at Kiowa Creek at Kiowa than at East Kiowa Creek at Elbert. The data also show that most of the sediment discharge at each site occurs during a few days each year. For example, a single storm on July 30, 1957, accounted for 99 percent of the total suspended-sediment discharge of 1,360 tons for the year at East Kiowa Creek at Elbert. The same storm produced only 28 percent of the total suspended-sediment discharge of 100,000 tons for the year at Kiowa Creek at Kiowa.

Spring runoff resulting from snowmelt was exceptionally large during 1960. Suspended-sediment discharge during March 22-31 at East Kiowa Creek at Elbert was 99 percent of the annual total for 1960, and at Kiowa Creek at Kiowa, 94 percent of the annual total. During this runoff, the percentage of sand in suspension was unusually high. This high percentage

Table 8.--Summary of periods of significant discharge of Kiowa Creek at K-79 Reservoir near Eastonville; East Kiowa Creek at Elbert[1], West Kiowa Creek at Elbert, and; Kiowa Creek at Kiowa

Water year	Kiowa Creek at K-79 Reservoir near Eastonville			East Kiowa Creek at Elbert			West Kiowa Creek at Elbert			Kiowa Creek at Kiowa		
	Drainage area 3.20 sq mi			Drainage area 28.6 sq mi			Drainage area 35.9 sq mi			Drainage area 111 sq mi		
	Water discharge		Sediment discharge	Water discharge		Sediment discharge	Water discharge		Sediment discharge	Water discharge		Sediment discharge
	cfs-days	acre-ft	tons	cfs-days	acre-ft	tons	cfs-days	acre-ft	tons	cfs-days	acre-ft	tons
1956												
May 23	0	0	0	0	0	0	---	---	---	89	177	8,400
June 28	0	0	0	0	0	0	---	---	---	4.4	8.7	360
July 2	0	0	0	0	0	0	---	---	---	20	40	1,600
16-17	4.0	7.9	24.5	0	0	0	---	---	---	0	0	0
31	0	0	0	0	0	0	---	---	---	264	524	43,000
Aug. 1-2	2/ 2.1	4.2	2/ 9.1	2/ 0	2/ 0	2/ 0	---	---	---	2/ 117	232	2/ 11,000
Total of periods	6.1	12.1	33.6	0	0	0	---	---	---	494.4	982	64,360
Total for year	---	---	---	0	0	0	---	---	---	529.0	1,050	---
1957												
May 9	0	0	0	0	0	0	---	---	---	189	375	12,000
May 15-June 13	2.3	4.6	4.6	0	0	0	---	---	---	627	1,240	10,900
June 14-15	5.9	12	30.4	0	0	0	---	---	---	40	79	80
July 10-11	6.8	13	27.8	0	0	0	---	---	---	0	0	0
20	.6	1.2	2.0	.1	.2	1.4	---	---	---	419	831	33,000
21-22	0	0	0	0	0	0	---	---	---	96	190	5,600
23-24	3.0	6.0	12.7	.1	.2	.3	---	---	---	69	137	480
25-29	0	0	0	0	0	0	---	---	---	165	327	4,050
July 30-Aug. 1	136	270	1,600	64.1	127	1,355	---	---	---	378	750	28,160
Aug. 2	---	---	---	0	0	0	---	---	---	5.8	12	14
3	---	---	---	.3	.6	3.6	---	---	---	48	95	2,600
4	---	---	---	.2	.4	.8	---	---	---	32	63	870
Aug. 6-7	2.8	5.6	12.5	0	0	0	---	---	---	3.5	6.9	3
Total of periods	157.4	312	1,690.0	64.8	129	1,361.5	---	---	---	2,072.3	4,110	97,757
Total for year	---	---	---	64.8	129	1,361.5	---	---	---	2,592.6	5,140	100,278
1958												
Nov. 1-12	---	---	---	0	0	0	---	---	---	61.8	123	84
Feb. 18-24	---	---	---	0	0	0	---	---	---	30.8	61	59
Mar. 2-4	.3	.6	3/	0	0	0	---	---	---	11.4	23	21
Mar. 18-May 7	14.1	28	8.2	0	0	0	---	---	---	275.0	545	711
May 8-18	3.2	6.3	3.6	0	0	0	---	---	---	119.4	237	1,630
19-28	1.2	2.4	.1	0	0	0	---	---	---	32.3	64	287
June 5-7	.3	.6	3/	0	0	0	---	---	---	17.5	35	226
July 19	2.4	4.8	5.3	1.0	2.0	18	---	---	---	0	0	0
20	.7	1.4	1.4	8.3	16	113	---	---	---	.1	.2	3/
Sept. 5	.1	.2	3/	.1	.2	2.0	---	---	---	0	0	0
6	.1	.2	3/	.1	.2	1.2	---	---	---	.2	.4	2
9-10	6.4	12.7	14.8	0	0	0	---	---	---	0	0	0
Total of periods	28.8	57	33.4	9.5	18	134.2	---	---	---	548.5	1,090	3,020
Total for year	---	---	---	9.5	18	134.2	---	---	---	790.4	1,590	3,288
1959												
Mar. 22-30	---	---	---	0	0	0	---	---	---	35.8	71	65
Apr. 1-30	6.4	13	.7	0	0	0	---	---	---	164.4	326	332
May 1-30	2.6	5.2	.1	0	0	0	---	---	---	158.3	314	334
June 1- 4	.2	.4	.1	0	0	0	---	---	---	13.2	26	17
July 16-17	9.8	19	35.6	0	0	0	---	---	---	.5	1	15
Aug. 4- 5	.8	1.6	.7	0	0	0	---	---	---	0	0	0
Sept. 9	.4	.8	.3	0	0	0	---	---	---	0	0	0
Total of periods	20.2	40	37.5	0	0	0	---	---	---	372.2	738	763
Total for year	---	---	---	0	0	0	---	---	---	446.0	884	819
1960												
Mar. 19-21	---	---	---	0.2	0.4	0.4	---	---	---	229	454	1,670
22-31	40.3	80	56.5	397.9	789	4,390.4	---	---	---	2,073	4,110	48,577
Apr. 1-12	13.0	26	1.2	5.9	12	1.6	---	---	---	236.6	469	886
13-30	5.6	11	.3	5.6	11	1.2	---	---	---	115.6	229	70
May 5- 8	3.5	6.9	1.2	6.4	13	8.8	---	---	---	38.8	77	76
9-15	2.9	5.8	.1	2.1	4.2	.2	---	---	---	43	85	25
16-20	1.5	3.0	.1	7.4	15	3.7	---	---	---	100	198	119
July 2	1.5	3.0	4.2	0	0	0	---	---	---	0	0	0
Total of periods	68.3	136	63.6	425.5	845	4,406.3	---	---	---	2,836.0	5,620	51,423
Total for year	---	---	---	432.0	858	4,406.7	---	---	---	2,961.6	5,880	51,531
1961												
Oct. 19	.3	.6	3/	0	0	0	---	---	---	3.6	7.1	2
Feb. 1-28	---	---	---	0	0	0	---	---	---	42	83	4.5
Mar. 1- 5	---	---	---	0	0	0	---	---	---	27.6	55	45
6-31	---	---	---	0	0	0	---	---	---	84.6	168	61
Apr. 1-13	1.1	2.2	1.0	.7	1.4	3/	---	---	---	68	135	21.9
May 14-19	1.4	2.8	.6	.2	.4	3/	---	---	---	44.7	89	34
June 1- 4	1.6	3.2	.7	0	0	0	---	---	---	26.9	53	78
5- 8	.4	.8	.1	0	0	0	---	---	---	33.3	66	94
9-16	.5	1.0	.1	0	0	0	---	---	---	31.7	63	20
July 7- 8	.1	.2	0	.1	.2	3/	---	---	---	3.5	6.9	5
11-12	.04	.1	0	0	0	0	---	---	---	98	194	940
13-14	.04	.1	0	0	0	0	---	---	---	20.5	41	11
28-31	.1	.2	0	.1	.2	.1	---	---	---	250	496	2,300
Aug. 1- 4	.5	1.0	.1	0	0	0	---	---	---	29.2	58	50
8	.6	1.2	.1	0	0	0	---	---	---	1.2	2.4	.2
12-16	.2	.4	0	2.3	4.6	1.4	---	---	---	16.1	32	19
17	.8	1.6	.2	0	0	0	---	---	---	7.0	14	11
30-31	.1	.2	0	0	0	0	---	---	---	20.7	41	75
Sept. 1- 4	.4	.8	3/	.1	.2	3/	---	---	---	26.6	53	43
5-10	.3	.6	3/	0	0	0	---	---	---	17.7	35	16
11-30	1.0	2.0	3/	.1	.2	3/	---	---	---	40.7	81	30
Total of periods	9.5	19	2.9	3.6	7.2	1.5	---	---	---	893.6	1,770	3,860.6
Total for year	---	---	---	3,7	7.4	1.6	---	---	---	973.2	1,930	3,886

See footnotes at end of table.

Table 8.--Summary of periods of significant discharge of Kiowa Creek at K-79 Reservoir near Eastonville; East Kiowa Creek at Elbert[1/], West Kiowa Creek at Elbert, and; Kiowa Creek at Kiowa--Continued

Water year	Kiowa Creek at K-79 Reservoir near Eastonville			East Kiowa Creek at Elbert			West Kiowa Creek at Elbert			Kiowa Creek at Kiowa		
	Drainage area 3.20 sq mi			Drainage area 28.6 sq mi			Drainage area 35.9 sq mi			Drainage area 111 sq mi		
	Water discharge		Sediment discharge	Water discharge		Sediment discharge	Water discharge		Sediment discharge	Water discharge		Sediment discharge
	cfs-days	acre-ft	tons	cfs-days	acre-ft	tons	cfs-days	acre-ft	tons	cfs-days	acre-ft	tons
1962												
Oct. 21-31	0.66	1.3	3/	0.1	0.2	3/	---	---	---	62.6	124	68
Nov. 3-14	---	---	---	.1	.2	3/	---	---	---	89.2	177	230
19-21	---	---	---	.4	.8	.1	---	---	---	7.8	15	.7
Dec. 5- 7	---	---	---	.3	.6	.1	---	---	---	17.8	35	22
Mar. 2- 4	---	---	---	.3	.6	3/	---	---	---	14	28	30
7-31	---	---	---	2.5	5.0	.3	---	---	---	207.2	411	268
Aug. 30-31	.50	1.0	.11	.0	0	0	---	---	---	0	0	0
Total of periods	1.16	2.3	.11	3.7	7.4	.5	---	---	---	398.6	790	618.7
Total for year	---	---	---	5.7	11	1.1	---	---	---	973.1	1,930	902.5
1963												
Feb. 1- 5	0	0	0	0	0	0	2.8	5.6	0.44	12.5	25	100
Mar. 16-28	0	0	0	0	0	0	5.6	11	.70	3.5	6.9	316.6
Apr. 4- 6	0	0	0	0	0	0	.6	1.2	3/	7.1	14	46
11-12	0	0	0	0	0	0	.6	1.2	3/	4.8	9.5	43
July 9	0	0	0	0	0	0	2.4	4.8	70	0	0	0
10	0	0	0	0	0	0	.1	.2	3/	0	0	0
11	0	0	0	0	0	0	0	0	0	.6	1.2	12
27	23.0	46	150	0	0	0	0	0	0	0	0	0
28	7.8	15	10	0	0	0	0	0	0	0	0	0
29	.5	1.0	.1	0	0	0	0	0	0	0	0	0
Aug. 12	.4	.1	3/	0	0	0	2.7	5.4	88	27	54	720
13	.4	.1	3/	0	0	0	6.0	12	980	58	115	1,200
14	.4	.1	3/	0	0	0	.2	.4	3/	2.4	4.8	13
24	2.0	4.0	6.0	0	0	0	0	0	0	.3	.6	.6
25	4.3	8.5	6.0	0	0	0	0	0	0	205	407	9,100
26	.1	.2	3/	0	0	0	0	0	0	115	228	2,600
27	.05	.1	3/	0	0	0	0	0	0	7.5	15	20
28	.05	.1	3/	0	0	0	0	0	0	4.5	8.9	8
Aug. 30-Sept. 1	.13	.3	3/	0	0	0	9.5	19	250	3.7	7.3	5.8
Sept. 7-10	1.0	2.0	.2	0	0	0	7.1	14	141	6.0	12	20
Total of periods	39.1	78	172.3	0	0	0	37.6	75	1,530.1	457.9	909	14,205.0
Total for year	---	---	---	0	0	0	86.6	171	1,532.3	533.6	1,060	14,228.8
1964												
Mar. 17-25	0	0	0	0	0	0	6.7	13	12.8	85.2	169	156
Mar. 28-Apr. 1	0	0	0	0	0	0	2.9	5.8	3.9	69	137	206
Apr. 2-22	0	0	0	0	0	0	5.3	11	1.7	106.1	210	76.4
May 29-31	.6	1.2	.8	0	0	0	1.4	2.8	1.2	13.7	27	8.4
July 25	2.8	5.6	1.6	0	0	0	0	0	0	0	0	0
26	.9	1.8	.1	0	0	0	0	0	0	0	0	0
Aug. 3	2.5	5.0	6.4	0	0	0	0	0	0	0	0	0
4	2.6	5.2	2.0	0	0	0	3.7	7.3	50	12	24	480
5	.4	.8	2.2	0	0	0	.1	.2	3/	31	61	380
6	.2	.4	.5	0	0	0	0	0	0	5.9	12	4.6
Total of periods	10.0	20	13.6	0	0	0	20.1	40	69.6	322.9	640	1,311.4
Total for year	---	---	---	0	0	0	44.5	89	73.4	440.3	874	1,345.6
1965												
June 17	122	242	280	2,280	4,520	290,000	710	1,410	89,000	770	1,530	56,000
18	59	117	250	380	754	24,000	150	298	5,700	2,130	4,220	290,000
19	7.5	15	18	20	40	110	50	99	700	110	218	2,400
20	.9	1.8	.4	10	20	33	20	40	48	45	89	440
July 7	.1	.2	3/	5	10	9	16	32	210	62	123	880
8	.05	.1	3/	.1	.2	3/	1.0	2.0	.2	90	179	1,600
9	.05	.1	3/	.2	.4	3/	.8	1.6	.1	10	20	17
10	.05	.1	3/	.1	.2	3/	.6	1.2	.1	8	16	10
Aug. 3	.06	.1	3/	.1	.2	3/	19	38	510	49	97	1,300
4	1.7	3.4	2.3	0	0	0	2.6	5.2	5	31	61	210
5	3.0	6.0	2.8	0	0	0	1.6	3.2	2	24	48	130
6	1.5	3.0	1.5	0	0	0	.7	1.4	.5	10	20	17
18-19	.2	.4	.1	.1	.1	3/	9.5	19	214	16.6	33	23
Total of periods	196.1	389.2	555.1	2,695.6	5,350	314,152	981.8	1,950	96,389.9	3,355.6	6,660	352,947
Total for year	---	---	---	2,731.7	5,420	314,213.3	1,118.7	2,220	96,437.8	3,626.7	7,200	353,121.4

1/ Published as Kiowa Creek at Elbert in U.S. Geological Survey publications.

2/ Period from April-September.

3/ Less than 0.05 tons.

of sand resulted from low concentrations of silt and clay, rather than from high concentrations of sand. Although large quantities of water may percolate downslope during snowmelt periods, sheet erosion commonly is low. The erosive effects of raindrop impact and of intense runoff are lacking. Therefore, snowmelt commonly contributes only small quantities of silt and clay to a stream. Also, the percentage of sand commonly is high even though concentration is low when runoff results from snowmelt because there is an abundant supply of sand in the streambed but little or no silt and clay.

Figures 1, 2, and 3 show the relation of instantaneous sediment discharge to water discharge. The curves represent average relations and cannot be used to compute the load for a specific day.

Figure 1 shows the relation of suspended-sediment and water discharge at East Kiowa Creek at Elbert and West Kiowa Creek at Elbert. The single curve is representative of both sites. Floodwater-retarding structures probably are the main reason for the low water and sediment discharges during the period of study at both stations. Water discharge at East Kiowa Creek at Elbert was very low between 1958 and 1965; during this time the channel became heavily vegetated; similar conditions prevailed at West Kiowa Creek at Elbert. The scatter of points in Figure 1 is due to seasonal variations, channel vegetation, differences in sediment discharge at identical water discharges on the rising and falling stages of high flows, differences in storm intensity and location, antecedent conditions of soil moisture, and antecedent conditions of streamflow. The curve probably indicates future water-sediment discharge characteristics.

Figure 2 shows the relation of suspended-sediment discharge to water discharge at Kiowa Creek at Kiowa. The difference between the two curves may represent the reduction in suspended-sediment discharge due to structural controls and other conservation measures applied during the period of study.

The curves in Figure 3 illustrate the effects of runoff during March, April, May, and early June on the sediment-water discharge relation. The upper curve shows spring runoff from rainfall or rainfall superimposed on snowmelt that occurred during March - May in 1957-59. The lower curve shows spring runoff that is composed only of snowmelt such as occurred during March 1960. For any given year, the relation of suspended sediment to water discharge during the spring depends on the ratio of snowmelt runoff to rainfall runoff.

The particle size distribution of suspended sediment for Kiowa Creek at Kiowa is shown graphically in Figure 4. The 1956-57 period more nearly represents conditions before widespread project development. These data include a general reduction of fine sediment with time and thus can be attributed to conservation measures installed during the period.

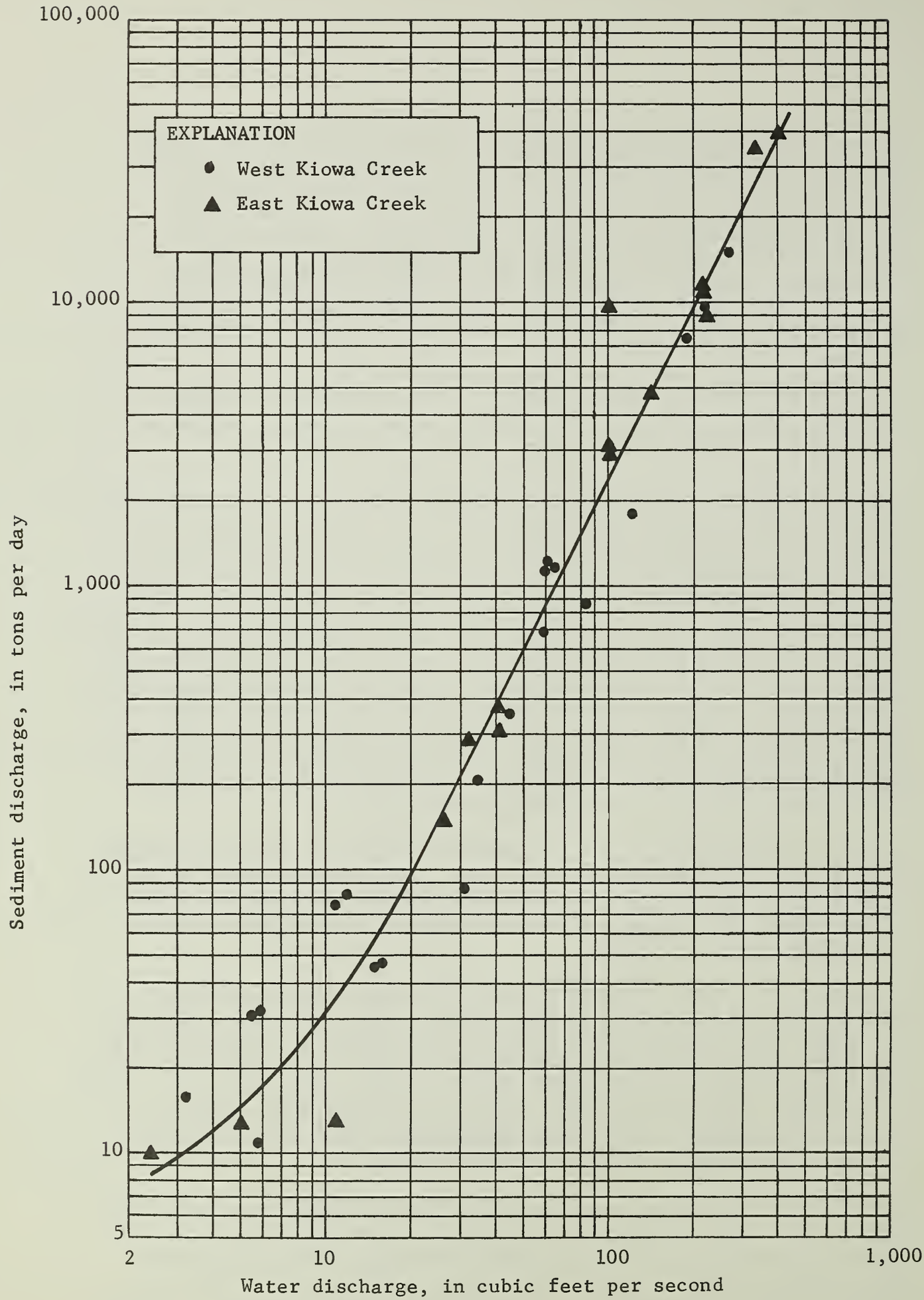


Figure 1.--Sediment and water discharge relation, East Kiowa Creek at Elbert and West Kiowa Creek at Elbert.

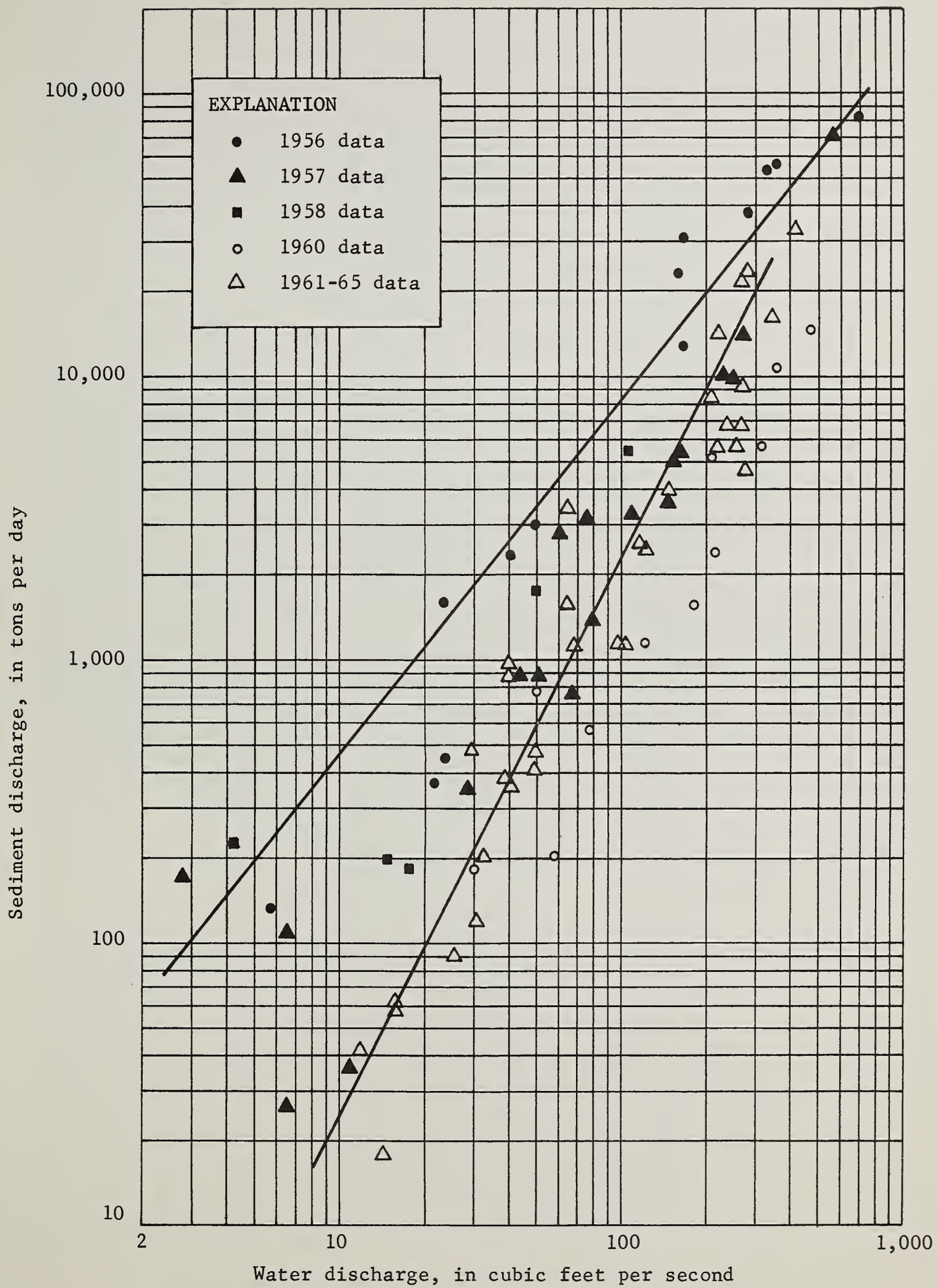


Figure 2.--Sediment and water discharge relation, Kiowa Creek at Kiowa.

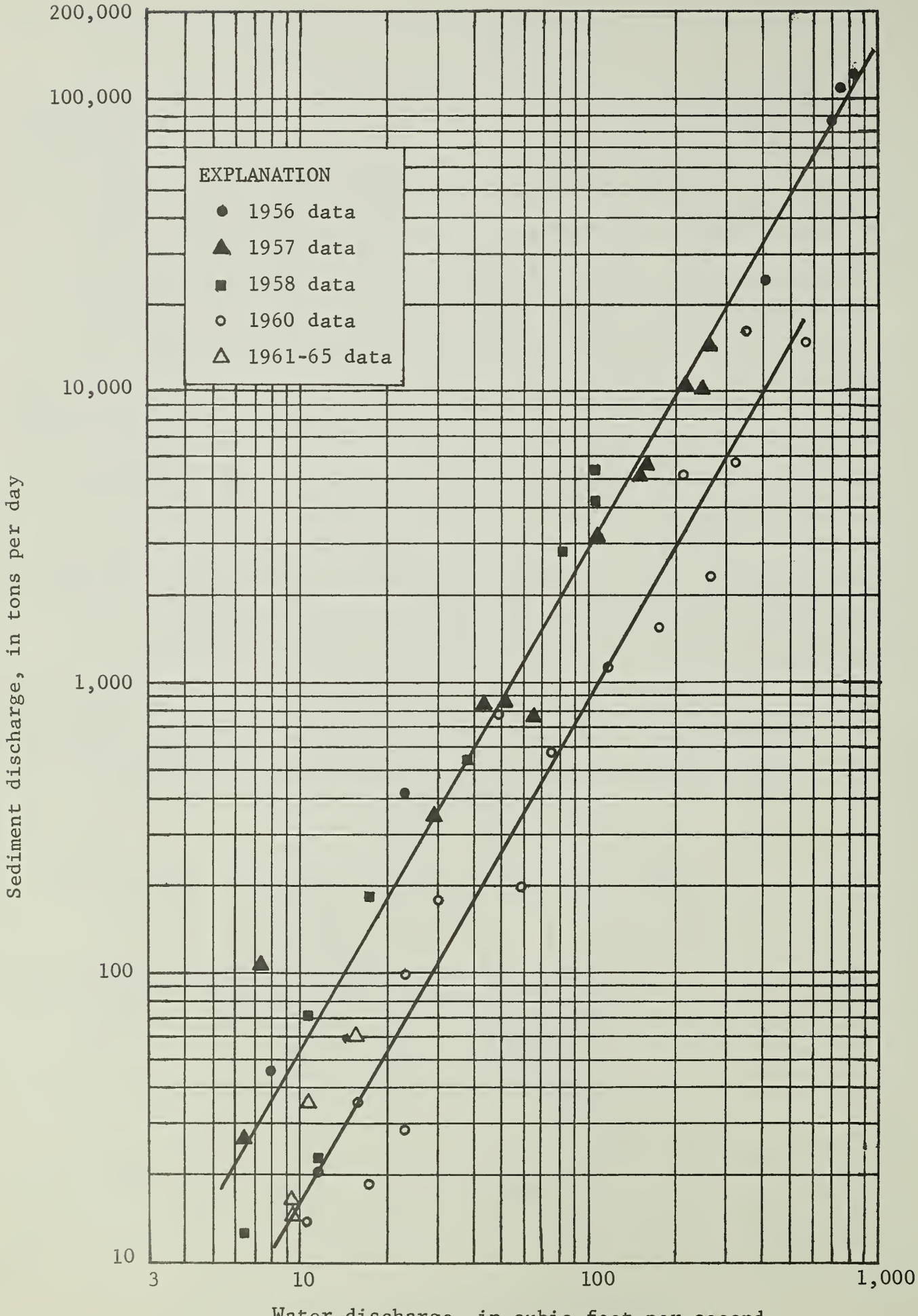


Figure 3.--Suspended sediment, and water discharge relation for spring runoff events, Kiowa Creek at Kiowa.

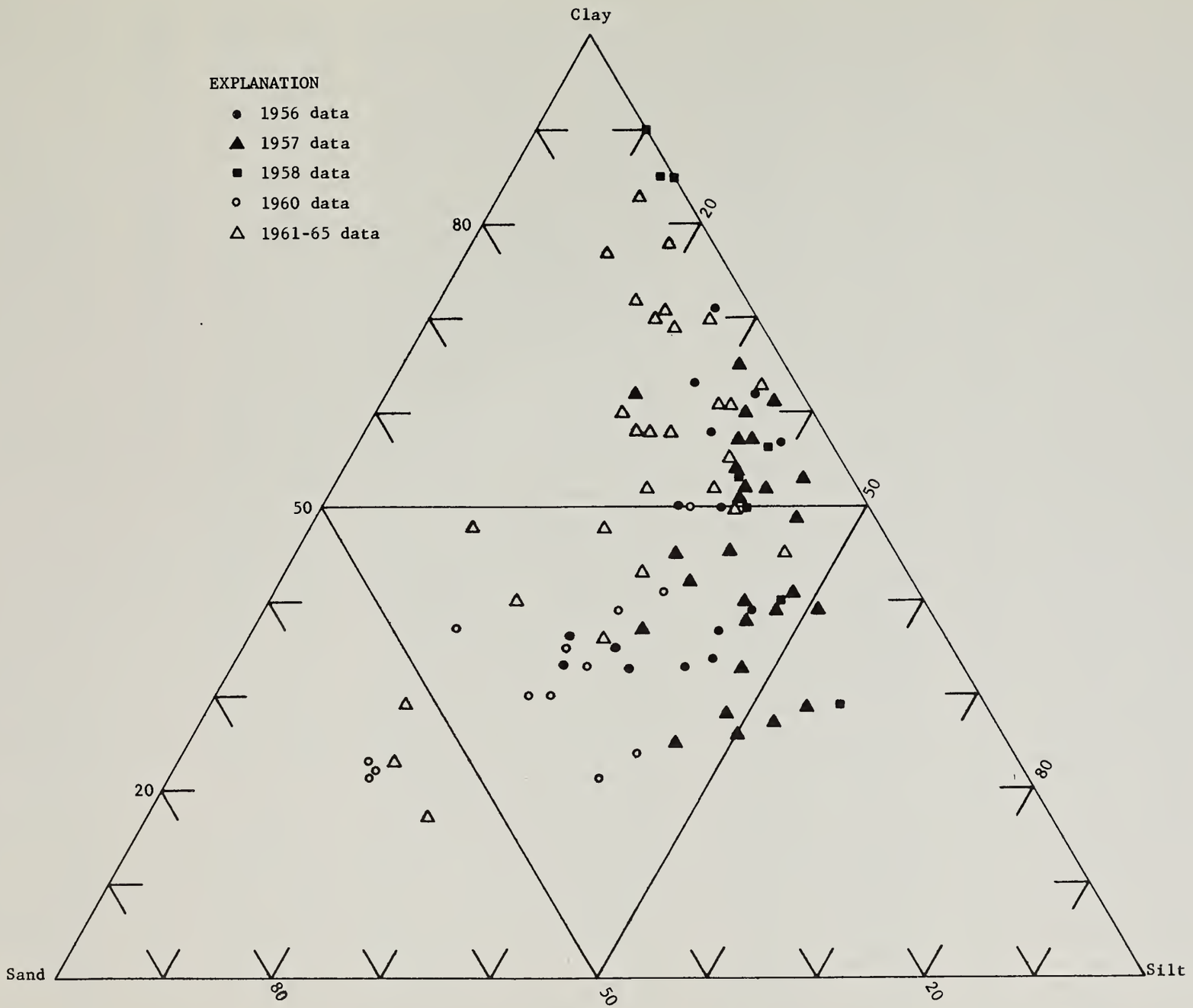


Figure 4.--Particle-size distribution of suspended sediment, Kiowa Creek at Kiowa.

Total Sediment Discharge

The total sediment discharge of a stream is composed of the suspended load and the bedload. Bedload cannot be measured directly, but total sediment discharge can be computed by several methods. Some of the methods for computing total sediment discharge have been discussed by Colby and Hembree 1/ and Hubbell and Matejka 2/. The modified Einstein procedure requires concurrent measurements of suspended-sediment, bed material, and streamflow parameters. The flow characteristics in Kiowa Creek change very rapidly during any period of major runoff, consequently it is extremely difficult to obtain concurrent data on the required parameters. Therefore, only a few total load approximations could be made for East Kiowa Creek at Elbert and for Kiowa Creek at Kiowa.

Kiowa Creek at Kiowa has a constructed channel that bypasses a former natural meander. The steep narrow walls of the channel form a constriction of the channel during high flows. Evidence indicates that all or most of the sediment is in suspension at discharges above a few hundred cfs.

Table 9 gives the results of total load computations for Kiowa Creek at Kiowa. The data indicate that the unmeasured part of the sediment load ranges from 30 to 60 percent of the total sediment load at this section.

Table 9. Total sediment discharge, Kiowa Creek at Kiowa, Colorado

Date	Discharge (cfs)	Measured Suspended Sediment		Total Sediment Discharge--Modified Einstein Method (tons per day)	Unmeasured Sediment Discharge--(tons per day)
		Concentration (ppm)	Discharge (tons per day)		
May 23, 1956	158	24,000	10,240	15,920	5,680
May 17, 1957	249	14,900	10,000	21,200	11,200
March 25, 1960 11:30 a.m.	254	5,680	3,900	9,380	5,480
March 25, 1960 7:25 p.m.	472	11,000	14,000	32,300	18,300
July 7, 1965 6:45 p.m.	225	28,600	17,400	25,100	7,700

1/ COLBY, B. R., and HEMBREE, C. H. COMPUTATIONS OF TOTAL SEDIMENT DISCHARGE, NIOBRARA RIVER NEAR CODY, NEBRASKA.
U. S. Geological Survey Water-Supply Paper 1357 : 187 p. 1955.

2/ HUBBELL, D. W., and MATEJKA, D. Q. INVESTIGATIONS OF SEDIMENT TRANSPORTATION, MIDDLE LOUP RIVER AT DUNNING, NEBRASKA.
U. S. Geological Survey Water-Supply Paper 1476 : 123 p. 1959.

Channel Profiles and Cross Sections

Surveys of the channel profile and cross sections were made in 1956 by the Soil Conservation Service and in 1962 and 1965 by the Geological Survey. In 1956, watershed protection measures in a minor part of the project area had no significant effect on mainstem channel characteristics. By 1962, the major detention structures had been completed and intensive conservation practices had been installed on much of the area; the effect of these structures and practices on channel characteristics increased progressively from 1956 to 1962. Maximum planned runoff control was in effect from 1962 to 1965.

The average slope of East Kiowa Creek from sections 15 and 16, T.11 S., R.64 W., to the confluence with West Kiowa Creek is 0.82 percent or 43 feet per mile. The profile shows irregular steps with the slope ranging from about 0.63 to about 1.53 percent. The profile slope did not change appreciably between 1956 and 1965. Minor aggradation occurred at some cross sections between 1956 and 1962. Most of the aggraded material was removed by flow resulting from the major storm of June 17, 1965; a tendency toward widening rather than deepening of the channel was evident. The net effect between 1956 and 1965 was the maintenance of about the same average slope, with aggradation at some sections, and widening of the stream channel at some sections.

The average slope of West Kiowa Creek from section 7, T.11 S., R.64 W., to its junction with East Kiowa Creek is 0.79 percent or 41.7 feet per mile. The profile shows a range in slope from about 0.60 to about 1.10 percent in relatively long, more regular steps than the East Kiowa Creek profile. The slope did not change significantly between 1956 and 1965. The channel cross sections showed a distinct tendency to aggrade between 1956 and 1962. The 1965 survey showed that some cross sections degraded but not to the level of 1956. West Kiowa Creek also showed a tendency to widen but to a lesser extent than East Kiowa Creek upstream from Elbert. The net effect between 1956 and 1965 was the maintenance of about the same average slope, aggradation at several cross sections, and slight or no widening of the channel.

The average slope of Kiowa Creek from the junction of West Kiowa and East Kiowa Creeks to Kiowa is 0.65 percent or 34 feet per mile. The slope did not change appreciably between 1956 and 1965. A distinct tendency toward widening of the channel is evident from the cross-section surveys; only minor aggradation or degradation occurred at the different sections.

Reservoir Sedimentation Surveys

In 1956 and 1957, the Soil Conservation Service installed monumented transverse ranges in the reservoir basins above five floodwater-retarding structures. The purpose of these ranges was to permit measurement of sediment deposits within the reservoirs by resurvey of points along the ranges. The ranges were laid out in a 50-foot grid pattern with additional points at topographic breaks. The dates of the original surveys were as follows: K-79 in August 1956, B-9 in July 1956, J-33 in July 1956, R-3 in July 1956, and Q-51 in June 1957. Sediment deposition at the time of these surveys was negligible.

In August 1957, a resurvey of K-79 reservoir was made following the storm of July 30, 1957. During this storm, the total inflow into K-79 was 270 acre-feet of water, of which 107 acre-feet were discharged through the emergency spillway and 163 acre-feet through the principal spillway. The resurvey was made on every fourth range within the reservoir basin. A total of 2.65 acre-feet of sediment was measured below the crest of the emergency spillway. Most of this sediment was probably deposited on July 30-31.

A resurvey of K-79 reservoir was made in October 1961 by the Agricultural Research Service. At that time five additional basin ranges were established.

Resurveys of the five sample reservoirs were made by the Soil Conservation Service in the summer of 1965 and winter of 1966 following the large flood of June 17, 1965. In K-79, J-33, R-3, and Q-51, large flows occurred through the emergency spillways during this flood. In B-9, water rose above the principal spillway inlet. The dates of the resurveys were as follows: K-79, B-9 and J-33 in July 1965, R-3 in March 1966, and Q-51 in January 1966. Results of these surveys and relevant features of the reservoirs and their drainage areas are shown in Table 10.

The combined drainage area of the five sample reservoirs is 8.37 square miles. Although there is a wide range in the characteristics of the drainage basins they are generally representative of the upland watershed area. The area controlled by the sample structures comprises 11.8 percent of the total area controlled by the 60 floodwater-retarding structures in the watershed.

Rates of sediment accumulation varied from 0.05 to 0.39 acre-foot per square mile per year, with an average of 0.22 acre-foot for the five reservoirs.

Average annual capacity losses of total storage range from 0.11 to 0.73 percent for the five sample structures. Average annual capacity losses of allotted sediment pools range from 0.33 to 3.07 percent, with an average of 1.84 percent. This average loss for the five structures is slightly less than the planned rate of 2 percent.

The percentages of the total sediment deposits occurring within the allotted sediment pools range from 48 percent at K-79 to 100 percent at B-9. The average for the five structures is 74 percent.

Range Evaluation Studies

The objective of the range evaluation studies 1/ was to determine changes in vegetation resulting from protection against grazing. In 1955, five study sites were selected and enclosures were built. These sites were on native rangeland above floodwater-retarding structures being studied for sediment deposition and other factors. Each of the range study areas consisted of paired sample areas 100 feet by 100 feet square, with one in each pair protected from grazing by a four wire fence. Forage production was measured in 1956 and annually through 1965.

1/ FISH, E. B. SECONDARY SUCCESSION ON UPPER KIOWA CREEK WATERSHED. Master's Thesis. On file, library, Colorado State University. May 1966.

Table 10. Reservoir sedimentation surveys of 5 sample structures, Kiowa Creek Watershed, Colorado, March 1966

		Structure				
	Unit	K-79	B-9	J-33	R-3	Q-51
Total drainage area	Sq.Mi.	3.20	0.64	1.12	2.82	0.59
Net sediment contributing area	Sq.Mi.	3.17	0.63	1.11	2.79	0.59
Date storage began	Month	June	Dec.	July	July	Sept.
	Year	1955	1955	1956	1956	1956
Original storage capacity:						
Sediment pool	Acre-ft.	24.37	16.50	4.87	47.70	9.09
Flood control pool	Acre-ft.	105.14	32.86	37.68	99.89	23.21
Total	Acre-ft.	129.51	49.36	42.55	147.59	32.30
Length of watershed	Mile	3.2	1.2	1.5	1.9	1.0
Average width of watershed	Mile	1.1	0.5	0.7	1.5	0.6
Period of deposition	Year	10	10	9	10	9
Accumulative sediment deposits:						
Sediment pool	Acre-ft.	3.60	0.55	0.38	5.62	1.93
Flood control pool	Acre-ft.	3.88	----	0.16	3.75	0.20
Total	Acre-ft.	7.48	0.55	0.54	9.37	2.13
Average annual	Acre-ft.	0.75	0.06	0.06	0.94	0.23
Average annual per sq. mi.	Acre-ft.	0.24	0.10	0.05	0.34	0.39
Deposition within sediment pool	Percent	48	100	70	60	91
Storage loss, percentage of total capacity:						
Period total	Percent	5.77	1.11	1.27	6.35	6.59
Average annual	Percent	0.58	0.11	0.14	0.64	0.73
Storage loss, percentage of allotted sediment capacity:						
Period total	Percent	30.70	3.33	11.09	19.64	23.43
Average annual	Percent	3.07	0.33	1.23	1.96	2.60

Livestock grazing on the rangeland of the Kiowa Creek Watershed is being managed to prevent deterioration of native vegetation. Range evaluation studies during the 1956-65 period indicated that native range plant cover has improved. Improvement under grazing use almost equals that in test plots under complete protection from livestock grazing. Range evaluation studies also led to the conclusion that moderate grazing use under conservation treatment resulted in sufficient plant cover to reduce runoff and erosion.

Range improvement on the grazed areas was indicated by the decrease in the cover formed by blue grama, a short grass, and an increase in the amount of bare ground. This is to be expected before taller grasses can become established and replace blue grama. Grasses important in potential or climax plant communities were generally more abundant at the end of the study period than they were at the beginning. These included June grass, western wheatgrass, and mountain muhly. All are rated good to excellent forage plants. The grazed pastures all showed an increase in total production at the end of the study period.

Vegetation inside and outside the enclosures was measured and tested statistically to determine similarity of the vegetation which had been grazed to that which had been protected from grazing during the study period. The following table presents these comparisons in terms of coefficients of community similarity: (A coefficient of 1.000 is equivalent to 100 percent similarity.)

Study Site	1956 Outside/Inside	1960 Outside/Inside	1965 Outside/Inside
K-79	.896	.810	.776
Q-51	.928	.811	.871
B-9	.907	.816	.887
J-33	.937	.829	.764
R-3	.885	.792	.796

Range sites and total average annual forage production for the 10 years of the study were as follows: (Yields were obtained inside the enclosures.)

Study Site	Range Site	Total Annual Yields (Pounds per acre)	
K-79 and B-9	Sandy Divide	Average:	1067
		High:	1365
		Low:	725
Q-51 and R-3	Loamy Divide	Average:	1298
		High:	1935
		Low:	640
J-33	Mountain Loam	Average:	1607
		High:	2256
		Low:	750

Range study plot outside the enclosure, in the drainage area of structure J-33, 1965. E-1

Range study plot inside the enclosure, in the drainage area of structure J-33, 1965. E-2

Economic Studies

A benchmark survey that included all farms in the watershed was made in 1954 to establish farm characteristics, land use, crop and pasture production, and flood plain damages. Information from these farm interviews was used to determine watershed conditions before the installation of the works of improvement. Farm surveys to obtain the same information were made in 1960, at which time the project was essentially completed, and in 1965, approximately 5 years after project completion.

Information on flood plain land use, production, and flood damages was obtained annually commencing in 1955 and continuing through 1965. All the farm operators with flood plain lands on East Kiowa Creek and Kiowa Creek were contacted each year. The flood plain study area (5,790 acres) included all fields that had some area within the flood plain. In addition, all non-agricultural damages were estimated annually based on information obtained from county road supervisors and other local people. Information on upland crop use and yields for eight selected areas was also collected annually.

Total Watershed

Land Use

Information on land use for the 75,520 acres within the Kiowa Creek Watershed is given in Table 11. The information shown is the average for the year in which the farm interview was made and the previous year. To some extent this averages out extremes caused by drought or other unusual situations. The 1953-54 information is representative of preproject conditions, the 1959-60 data represents conditions with most of the project works of improvement installed, and the 1964-65 data are representative of conditions in the area approximately 5 years after the project was completed.

At the start of the evaluation period approximately 8,600 acres, or 11 percent of the watershed area, were planted to crops. At the end of the evaluation period approximately 6,800 acres or 9 percent of the area was planted to crops. Most of the crop acreage reduction was planted to grass or permanent pasture. This adjustment was needed to more nearly utilize the land within its capabilities.

Irrigated cropland acreage averaged about 750 acres during the evaluation period. Of this, 68 percent was devoted to hay crops and 25 percent to corn or sorghum forage production. The balance was devoted to small grains or new seedings of hay crops.

The acreage of idle, summer fallow, feed-grain program, and soilbank lands approximately doubled during the evaluation period. A part of this acreage was crop and pastureland bought for speculative purposes and allowed to remain idle. A considerable acreage was also under soilbank or feed-grain program contracts. The acreage of waste, stream channel, and other nonproductive flood plain lands was reduced from 1,222 acres at the beginning of the project period to approximately 854 acres in 1964. The flood of 1965 damaged almost 400 acres of flood plain land to such an extent that they were nonproductive.

The total acres of waste, stream channel, and other nonproductive flood plain lands was approximately 1,253 acres in December 1965. The loss of redeveloped flood plain land may cause farm operators to decide that protection provided for some flood plain lands is not sufficient to make intensive development profitable.

Land in other uses such as townsites, farmsteads, roads, fences, residential sites, and boy scout camp areas has increased from 802 acres to approximately 4,856 acres. Of the 4,054 acres increase in other uses, 2,026 acres are devoted to boy scout camp areas, 1,682 acres are being subdivided into residential lots, and 346 acres were used for farmsteads, roads, and other miscellaneous uses.

Table 11. Land use, Kiowa Creek Watershed, Colorado, 1953-54, 1959-60, 1964-65 averages

Land Use	1953-54 Average (Acres)	1959-60 Average (Acres)	1964-65 Average (Acres)
Cropland			
Alfalfa	1,366	1,603	1,895
Mixed and native hay	605	696	938
Barley	137	338	79
Beans (dry)	34	27	27
Corn (silage)	1,964	939	381
Oats	1,549	1,235	1,177
Rye	289	483	153
Sorghum (forage)	258	172	474
Wheat	2,411	1,610	1,688
Subtotal	8,613	7,103	6,812
Pasture and rangeland			
Grassland	46,800	45,756	44,300
Wooded grassland	14,500	14,400	11,700
Subtotal	61,300	60,156	56,000
Idle, summer fallow, feed-grain program and soil bank	3,583	6,258	6,799
Waste, stream channel, etc.	1,222	947	1,053
Other 1/	802	1,056	4,856
Total	75,520	75,520	75,520

1/ Includes townsites, farmsteads, roads, fences, residential sites and Boy Scout Camp areas.

Crop and Pasture Production

Crop yields are quite variable in this watershed, which makes the analysis of conservation benefits extremely difficult. Variations in rainfall, hail, frost, or flooding affect crop yields to such an extent that, without check plots or areas, conservation benefits cannot be adequately analyzed. The percent of crop acreage harvested is one of the most significant factors affecting crop production or the value of crops produced. For the watershed area, 71 percent of the crop acreage shown in Table 11 was harvested in the 1953-54 crop years, 87 percent was harvested in 1959-60, and 80 percent was harvested during 1964-65. Weighted average crop yields for the selected years within the evaluation period are shown in Table 12.

Table 12. Average crop yields, Kiowa Creek Watershed, Colorado, 1953-65

Crop	Unit	1953	1954	1959	1960	1964	1965	Average 1953-65
Alfalfa hay	ton	1.2	.9	1.8	1.4	1.3	1.7	1.4
Mixed and native hay	ton	.9	.7	1.2	1.1	.7	.9	.9
Small grain hay	ton	.9	.3	.8	.6	.5	.8	.6
All hay	ton	1.0	.6	1.5	1.1	.9	1.2	1.1
Oats	bu.	15	10	21	16	11	31	18
Rye	bu.	10	9	11	8	--	--	9
Wheat	bu.	16	8	28	23	13	12	17
Barley	bu.	25	7	24	23	7	35	22
Corn (silage)	ton	4.3	3.2	4.6	3.9	6.0	4.3	4.1
Corn (fodder)	ton	1.2	1.1	1.2	1.1	1.2	1.2	1.1
Sorghum (forage)	ton	.8	1.0	1.1	.9	1.0	1.0	1.0
Beans (dry)	lbs.	--	200	411	--	345	200	300

The most significant change in crop production was a 44 percent increase in the hayland acreage (alfalfa, mixed, and native hay). At the start of the evaluation period there were 1,971 acres of hayland and by 1964-65, there were 2,833 acres. Concurrently, the acreage of corn dropped from 1,964 to 381 acres. The reason for this change is evident from the low average yields of corn for silage (4.1 tons) and corn for fodder (1.1 tons). Since the average yield of alfalfa hay is 1.4 tons per acre, farmers can raise about the same quantity of feed with less expense and labor with alfalfa.

Wheat is the major cash crop in the watershed, accounting for 25 percent of the land in crops and approximately an equal acreage of summer fallow land. During the evaluation period about 1,900 acres of wheat were planted each year, principally in the upland areas. Approximately 80 percent was harvested for grain. The weighted average yield for all wheat harvested was 17 bushels per acre. The average yield for individual years varied from 8 to 28 bushels.

In 1962 a pasture evaluation study was added to the economic studies to provide additional information on pasture or rangeland use and livestock gains. Ten individual pastures totaling 4,992 acres were included in the study. The range sites involved were Sandy Grassland, 1,875 acres; Loamy Grassland, 1,446 acres; Pine Grassland, 1,299 acres; and seeded pasture go-back, 372 acres. Almost all of this pastureland is in fair or good condition with a small area in excellent condition. During the 4 years these pastures were studied they all received proper use or under use. Average gain per acre amounted to 15.5 pounds with an average stocking rate of 3.2 acres per animal unit month of grazing (Table 13). In 1962 and 1964 some of the pastures in the study were not grazed. The stocking rates for pastures varied from a low 4.7 acres per animal unit month of grazing in 1963 to a high of 2.1 acres per animal unit month of grazing in 1965.

Table 13. Pasture use and livestock gains for special pasture study area, Kiowa Creek Watershed, Colorado, 1962-65

Year	Total Acres Pastured	Gain Per Acre	Acres Per AUM Grazing
	(Acres)	(Pounds)	(Acres)
1962	4,331 1/	11.8	3.4
1963	4,992	11.6	4.7
1964	4,527 1/	16.7	3.5
1965	4,992	21.5	2.1
1962-65 Average	4,710	15.5	3.2

1/ In 1962 and 1964 eight of the ten pastures were grazed.

The value of crop and pasture production in the watershed (in terms of long-term project prices 1/) is shown in Table 14. Production values reflect changes in cropping patterns, crop yields, and changes in land use only, as constant prices were utilized throughout. To further isolate the effect of changed land use, weighted average yields for the 1953-54 base period and long-term projected prices were used in conjunction with the average use of land in 1959-60 and 1964-65 to compute the average value of production for these periods. These values are shown in the second part of Table 14. They indicate that there has been a decline in the intensity of land use during the evaluation period, which was offset by an increase in crop yields so that total value of production increased slightly.

Table 14. Value of crop and pasture production (computed using long-term project prices), Kiowa Creek Watershed, Colorado, 1953-65

Item	1953-54 Average	1959-60 Average	1964-65 Average
	(Dollars)	(Dollars)	(Dollars)
Value computed from observed yields: (long-term projected prices)			
All crops harvested	123,173	177,632	121,426
Pasture	63,696	67,018	72,325
Total	186,869	244,650	193,751
Value computed from 1953-54 weighted average yields: (long-term projected prices)			
All crops harvested	123,173	121,387	104,516
Pasture	63,696	59,796	57,171
Total	186,869	181,183	161,687

Size and Type of Farm and Ranches

Information obtained on some of the farms by the farm survey was not sufficient to allow determination of size and type. Therefore, this information for some of the farms was left out of the following summaries. In general, headquarters of the omitted farms were not in the watershed area. In 1954, 83 percent of the farms contained between 180 and 1,999 acres, while in 1965, 68 percent of the farms were in this range (Table 15). During the evaluation period, there was a significant increase in the number of farms with from 50 to 179 acres. Farms of this size do not provide an economic unit and are operated by part-time operators or are used as residential farms. Farms over 1,000 acres in size increased in number from 26 to 36 during the same period.

1/ U. S. DEPARTMENT OF AGRICULTURE. AGRICULTURAL PRICE AND COST PROJECTIONS. U. S. Department of Agriculture, Agricultural Research Service and Agricultural Marketing Service. September 1957.

Table 15. Farms by size, Kiowa Creek Watershed, Colorado, 1954-60-65

Farms by Size	1954 Farm Survey		1960 Farm Survey		1965 Farm Survey	
	(No.)	(Percent)	(No.)	(Percent)	(No.)	(Percent)
Under 50 acres	1	1.1	0	---	0	---
50 to 179 acres	3	3.4	7	8.1	9	11.0
180 to 499 acres	28	31.8	21	24.5	19	23.2
500 to 999 acres	30	34.1	24	27.9	18	21.9
1,000 to 1,999 acres	15	17.1	18	20.9	19	23.2
2,000 or more acres	11	12.5	16	18.6	17	20.7
Total	88	100.0	86	100.0	82	100.0

The resources of this area are best suited to a range-livestock economy. In 1965, almost 75 percent of the farm operators reported livestock to be the major source of farm income (Table 16). This was an increase from 1954 when only 45 percent of the farm operators reported livestock as the major source of income. Perhaps the most significant change is the reduction in number of dairy farms, with only three operators reporting dairy products as the major source of farm income in 1965 compared to 25 operators in 1954. There was also a 58 percent reduction in the number of cash crop farms. Farms listed as other are mostly residential farms where the operator has a full-time off-farm job.

Table 16. Farms by major enterprise, Kiowa Creek Watershed, Colorado, 1954-60-65

Major Enterprise	1954 Farm Survey		1960 Farm Survey		1965 Farm Survey	
	(No.)	(Percent)	(No.)	(Percent)	(No.)	(Percent)
Livestock 1/	40	45.5	60	69.8	61	74.4
Dairy	25	28.4	11	12.8	3	3.7
Poultry	0	---	1	1.2	1	1.2
Cash crop	12	13.6	4	4.6	5	6.1
Other	11	12.5	10	11.6	12	14.6
Total	88	100.0	86	100.0	82	100.0

1/ Other than poultry or dairy.

In 1965, 37 (or 47 percent) of the farm operators interviewed stated that they had some form of off-farm employment. Of this number, 20 had full-time off-farm employment, eight were employed off the farm more than 100 days per year, and nine were employed off-farm less than 100 days per year.

Livestock Numbers

Numbers of livestock owned by operators with land in the Kiowa Creek Watershed have remained relatively stable during the evaluation period (Table 17). In general, livestock numbers were lowest in 1960 and highest in 1965. The most significant trend was the reduction in numbers of milk cows from 715 in 1954 to 176 in 1965. Horse numbers have increased with the increased recreation use of the watershed lands. There also appears to be a trend toward stocker or feeder cattle rather than the traditional cow-calf operation.

Table 17. Livestock numbers owned by operators with land in the Kiowa Creek Watershed, Colorado, 1954-60-65

Type of Livestock	December 31, 1954	January 1, 1960	January 1, 1965
Beef cows	2,230	2,118	2,544
Milk cows	715	474	176
Heifers (replacement) 1/	855	798	747
Steers and heifers 2/	170	823	1,421
Bulls	338 3/	144	100
Sheep	350	318	62
Horses	37	14	158

1/ Includes some that are sold as bred heifers.
2/ Stocker - feeders.
3/ Includes a number of purebred bulls for sale.

Farm and Ranch Tenure

Almost all the farmers or ranchers in the study area are owner-operators (Table 18). The percentage of farm operators owning all the land operated has averaged about 75 percent but the trend is toward fewer full owners. For Colorado as a whole, only about 50 percent of the operators are full owners. The trend has been toward fewer full owners, more part-owners and hired managers, while tenant-operated ranches remained relatively stable. In 1954, 92 percent of the land in the survey area was owned by operators of the individual farms. In 1965, this percentage had dropped to 89 percent.

Table 18. Tenure of the farm operators, Kiowa Creek Watershed, Colorado, 1954-60-65

Tenure of Operator	1954 Farm Survey		1960 Farm Survey		1965 Farm Survey	
	(No.)	(Percent)	(No.)	(Percent)	(No.)	(Percent)
Full owner	68	77.3	64	74.4	59	71.9
Part owner	13	14.8	17	19.8	14	17.1
Manager	0	---	1	1.2	4	4.9
Tenant	7	7.9	4	4.6	5	6.1
Total	88	100.0	86	100.0	82	100.0

The average age of farm operators in the Kiowa Creek Watershed during the evaluation period was about 52 with 50 percent or more of the farm operators in the age group from 46 to 64 years. In 1960, there were 17 farm operators over 65 years of age and in 1965 there were 14 operators in this age bracket. During the evaluation period, only about 27 percent of the operators of farms in this watershed were less than 45 years old. The relatively advanced age of the farm operators may have delayed the application of land treatment measures and the adoption of better farming practices.

A number of the farm operators in this watershed have lived all their lives on the farm they operate. In 1965, one of the operators had been living on his present farm for 76 years. In general, half of the farmers in this watershed have been on their present farms for over 10 years. The tenure of farm operators in this watershed has been relatively stable during the evaluation period.

Flood Plain

Flood Plain Land Use

Land use and crop production were studied annually to determine changes in land use, crop production, and benefits from more intensive use of flood plain lands. The flood plain study areas included all fields with some land in the flood plain. The flood plain study area included 5,790 acres with 2,725 acres along Kiowa Creek below Elbert and 3,065 acres along East Kiowa Creek. The gross value of crop and pasture production was used to measure the effects of land use changes in the flood plain areas. Average land use and value of production were computed for the 1953-54 base period, yearly values for 1955 through 1965, and average values for 1955-65 (Table 19). Year to year changes in value of production reflect differences in land use and yields only, since prices are held constant. 1/ However, these values do reflect the impacts of flooding and numerous climatic and biological variables which affect land use and yields.

The most important factor determining value of crops produced is percent of crops harvested. In the flood plain study area, 84 percent of the crops were harvested during the 1955-65 period, while only 73 percent of the crops were harvested in the 1953-54 base period. As a result of flooding, only 74 percent of the cropland was harvested in 1965. If the factor of yield variation is removed by using weighted average annual yields for the 1953-54 base period, the resulting value of production is more nearly a measure of land use. Using this criteria, the average increase in value of flood plain production would amount to $6,303 for the 1955-65 period.

1/ U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL PRICE AND COST PROJECTIONS. U. S. Department of Agriculture, Agricultural Research Service and Agricultural Marketing Service. September 1957.

Table 19.--Land use, percent of crops harvested, annual precipitation, crop yields, and value of production on floodplain study areas,[1] Kiowa Creek Watershed, Colorado, 1953-65

Item	Unit	Average 1953-54	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	Average 1955-65
Land use:														
Alfalfa	Acres	641	656	560	571	811	894	962	1,116	1,148	1,168	1,326	1,227	949
Mixed and native hay	Acres	245	164	203	202	182	264	213	227	217	219	268	239	218
Barley	Acres	15	44	44	53	58	54	--	20	10	--	--	--	26
Beans (dry)	Acres	3	--	--	--	16	34	--	13	--	--	--	--	6
Corn	Acres	455	500	602	568	321	337	314	113	188	89	130	32	288
Oats	Acres	162	220	116	221	135	76	207	220	134	4	20	97	123
Rye	Acres	43	60	47	39	92	106	41	17	17	17	--	6	40
Sorghums (forage	Acres	43	27	127	32	27	--	80	6	--	118	76	105	54
Wheat	Acres	51	31	--	70	--	92	13	105	31	103	53	82	100
Subtotal	Acres	1,658	1,702	1,699	1,756	1,642	1,857	1,830	1,837	1,745	1,718	1,873	1,788	1,804
Pastureland	Acres	2,961	2,948	2,797	2,909	2,813	2,945	2,904	2,985	2,995	2,976	2,785	2,710	2,852
Idle, soil bank, summer fallow	Acres	145	152	358	207	446	174	254	166	248	294	405	232	267
Waste and stream channel	Acres	1,026	988	936	918	889	814	802	802	802	802	727	1,060	867
Total		5,790	5,790	5,790	5,790	5,790	5,790	5,790	5,790	5,790	5,790	5,790	5,790	5,790
Percent of crops harvested	Per cent	73	79	82	93	91	84	92	93	89	84	87	74	84
Precipitation during the crop year (Oct.-Sept.) inches ave. for all stations:	Inches	14.29[2]	14.37[2]	9.71	22.08	20.09	14.94	13.20	21.04	11.77	15.41	11.40	21.66	16.13
Average crop yields:														
Alfalfa	Tons	1.2	1.5	1.8	2.5	1.9	2.1	2.0	1.8	1.3	1.2	1.3	1.9	1.7
Mixed and native hay	Tons	.8	1.4	.8	1.8	1.8	1.4	1.7	1.4	1.1	.6	.7	.8	1.2
All hay	Tons	1.1	1.4	1.5			1.9	1.8				1.2	1.6	1.6
Barley	bu.	--	25	8	6	9	50	--	9	--	--	--	--	17
Oats	bu.	8	5	--	31	15	--	25	14	6	--	--	30	22
Wheat	bu.	10	30	--	25	--	36	44	19	14	5	4	10	22
Corn (silage)	Tons	4.9	5.8	6.8	9.5	9.4	6.0	7.1	6.5	5.0	9.6	8.2	10.6	7.5
Corn (fodder)	Tons	1.3	1.2	1.0	2.5	2.0	1.1	1.1	1.4	1.2	2.0	1.7	--	1.3
Sorghum (forage)	Tons	1.9	1.7	2.0	2.5	2.0	--	1.2	1.2	--	1.2	2.0	1.8	1.7
Production value computed from observed yields: (Long-term prices):														
All crops harvested	Dollars	32,840	44,322	49,285	84,742	63,718	64,214	62,158	59,397	40,732	37,215	45,653	48,229	54,515
Pasture	Dollars	9,012	9,900	7,887	9,405	9,136	9,821	9,421	9,675	8,930	9,881	8,400	9,323	9,253
Total	Dollars	41,852	54,222	57,172	94,147	72,854	74,035	71,579	69,072	49,662	47,096	54,053	57,552	63,768
Production value computed from 1953-54 weighted average yields (Long-term prices):														
All crops harvested	Dollars	32,840	35,971	37,251	41,545	37,610	38,310	40,159	40,107	38,080	37,653	41,477	32,160	38,211
Pasture	Dollars	9,012	9,045	8,555	8,562	8,321	8,968	8,580	8,810	8,925	9,019	8,396	8,538	8,702
Total	Dollars	41,852	45,016	45,806	50,107	45,931	47,278	48,739	48,917	47,005	46,672	49,873	40,698	46,913

1/ Main Kiowa (2,725 acres) and East Kiowa (3,065 acres).
2/ Official records not available - Precipitation records from the Kiowa State Bank.

One of the most significant changes in land use observed in flood plain study areas was the reduction of corn acreage from 455 acres during the 1953-54 base period to 32 acres in 1965. During the same period, the acreage of alfalfa hay approximately doubled, increasing from 641 acres to 1,227 acres. During the last few years of the evaluation period, there was also a significant increase in the acreage of forage sorghums. These data indicate that there is a definite trend toward using more of the flood plain land for crops but at the same time there is a trend toward using the cropland less intensively. Casual factors for these trends are hard to identify. Increased size of operating units and the difficulty in obtaining farm labor are probably the most significant.

Resources available for this project evaluation did not permit separating project effects from the other variables in determining increased net returns in the flood plain study area. There has been a definite tendency for additional cropland to be developed in the flood plain study areas and the total feed or forage production has increased during the evaluation period. This is an extremely important factor in a livestock area which normally imports hay or other winter feed supplies.

Average annual benefits expected to accrue from more intensive use of flood plain lands were estimated at $21,980 annually in the amended work plan. The flood plain study areas as evaluated did not include the flood plain of West Kiowa Creek which has an estimated 2,514 acres in the flood plain. No attempt was made to estimate benefits from more intensive use on these lands. For the 5,790 acres in the flood plain study area, the average annual benefits for the 1955-65 period would probably be more than the $5,061 increase in gross returns indicated by comparing the 1953-54 average value of production with the 1955-65 average and using the 1953-54 base period average yields. Conversely, the benefits from more intensive land use would be considerably less than the $22,608 difference in gross value of production using observed yields for the two periods.

Flood Damages

Floodwater damage information was collected annually for the entire watershed for the 1955-65 period. Dollar value of these damages is shown in Table 20.

During the project installation period, there were 3 years in which measurable floodwater and sediment damages occurred. The total value of damages from 1955-60 amounted to $6,342. All of these damages occurred in the first 3 years of the project installation period. At this time, not enough structures had been completed to afford much protection to the flood plain lands.

For the first 2 years after the project was completed (1960-62), no measurable floodwater damages occurred in the watershed area. In 1963 and 1964, very minor flooding occurred with a total evaluated floodwater damage of $223. Local people were pleased with the watershed project and expressed the opinion that they needed a storm of sufficient intensity to test the structures of the entire watershed.

Table 20. Flood damages, Kiowa Creek Watershed, Colorado, 1955-65 1/

Item	Project Installation Period (1955-60)			With Project Installed (1961-65)			Total
	1955	1956	1957	1963	1964	1965	
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Floodwater damage							
Crop and pasture			356			29,525	29,881
Fences	390	76				15,557	16,023
Livestock						4,740	4,740
Buildings and machinery				100		3,016	3,116
Irrigation works						12,884	12,884
Other agriculture		200	1,000			9,723	10,923
Roads and bridges	550	570	775	50		58,366	60,311
Other non-agriculture	600					4,100	4,700
Subtotal	1,540	846	2,131	150		137,911	142,578
Sediment damages							
Flood plain deposition	80	420	1,325	33	40	16,595	18,493
Erosion damages							
Streambank erosion and channel scour						14,659	14,659
Total - all damages	1,620	1,266	3,456	183	40	169,165	175,730

1/ During the project installation period there were no damages in 1958, 1959, and 1960. With the project installed there were no damages during 1961 and 1962.

The storm of June 17, 1965, produced runoff amounts that were several times larger than the design capacity of some of the floodwater-retarding structures. Of the 60 floodwater-retarding structures, 27 had emergency spillway flow. This storm produced evaluated flood damages of $169,165 within the watershed area and contributed to the downstream flooding experienced in the South Platte River Basin from a series of storms the same week. Since damages from this storm were so much larger than others experienced during the evaluation period, a special section on damages and benefits from the storm of June 17, 1965, is included later in this report.

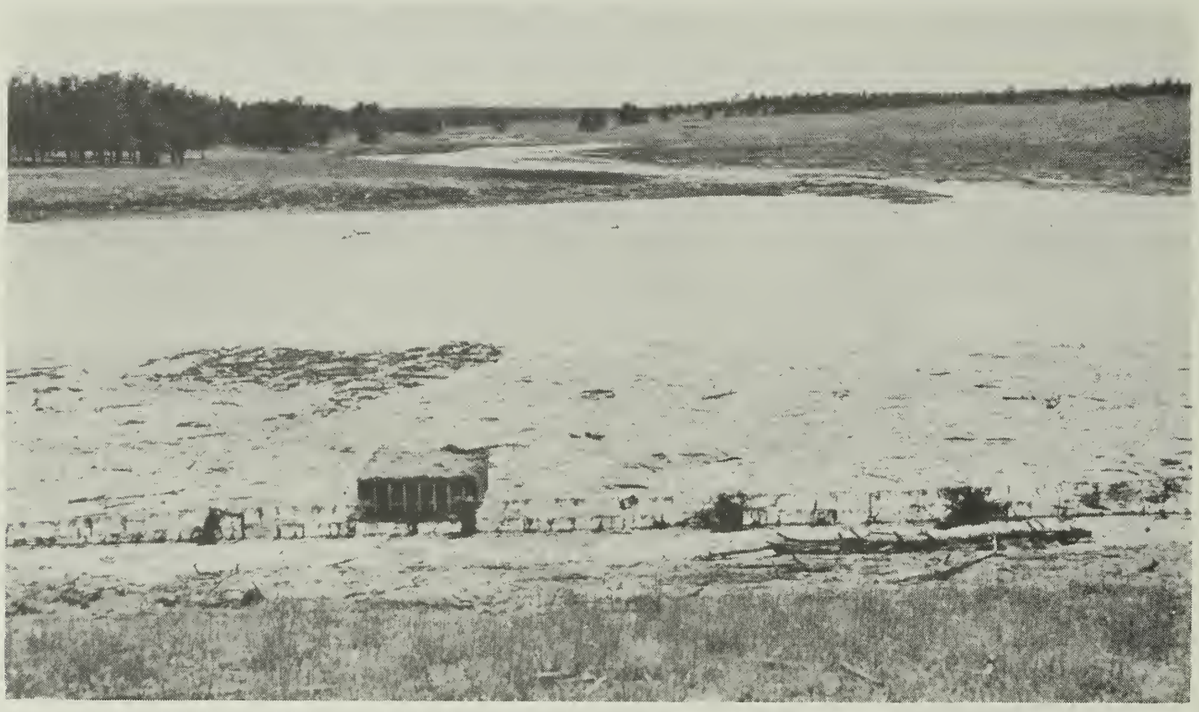
Storm frequencies were not assigned to the storms occurring during the evaluation period, therefore, no valid estimate can be made of long-term average annual floodwater damages either with or without the project. If it is assumed that the wide range in size of storms is normal for this area, it can be stated that for the 11-year period (1955-65) flood damages with the project amounted to $175,730, or an average of $15,975 annually. This period included the project installation period of six years. Furthermore, it is possible to conclude that floodwater damages without the project would have amounted to $307,405, or $27,946 annually. Thus, during the 11-year evaluation period, the project averted damages of $131,675 in the flood plain areas of the watershed. It cannot be inferred, however, that such damage reduction will be representative of any other time period, inasmuch as the frequencies of experienced storms are unknown and the project was not fully installed during the entire evaluation period.

Flood Plain Benefits

The full impact of the comprehensive soil and water conservation program installed under the Kiowa Creek Watershed Project was not ascertained by this study. A complete analysis of benefits requires a detailed hydrologic evaluation and collection and measurement of additional physical and economic data over a much longer period. This would not be justified, however, in view of the rapid advancement of watershed planning techniques since the initiation of this project. Under recent planning criteria the Kiowa Creek Watershed Project would be changed considerably, as to land treatment measures, structural measures, and estimated benefits.

Benefits from project measures were estimated annually after obtaining available information from SCS work unit personnel, local people, and county officials. The necessary hydrologic information to accurately estimate these flood damage reduction benefits were not available for individual storms, but the storm of June 17, 1965, was of such a magnitude that some peak flow estimates were computed as a basis for benefit evaluation.

Benefits from the reduction of erosion damages (channel trenching, and sheet or gully erosion) were not evaluated in monetary terms for the upland portions of this watershed. In general, however, gully and streambank erosion are not particularly active. The failure to evaluate upland erosion control benefits is a major deficiency of this study, considering that preproject average annual damages from erosion were estimated to be $20,030, and estimated project benefits from reducing these damages amounted to $15,230 annually.



Structure 1 P-10 near the headwaters of West Kiowa Creek after the flood of June 17, 1965. 10-241-4

Outflow tube of structure 1 P-10 operating June 18, 1965. 10-241-3

These estimated damages and benefits amounted to 37 percent and 24 percent respectively of the total estimated for the watershed.

The effect of the land treatment (B Measures) program in reducing damages was not determined, but it was a major factor in preventing greater floodwater, sediment, and erosion damages to the watershed lands. The seeding of approximately 5,000 acres to permanent cover was probably the most important single land treatment measure in reducing these damages.

Estimated benefits from the reduction of damages by the project during the evaluation period (1955-65) amounted to an estimated $131,675 (Table 21). Of this amount, $115,341 in benefits resulted from the reduction of floodwater damages and $16,334 from reduction of sediment and erosion damages on the flood plain areas.

Benefits from project measures during the installation period (1955-60) were estimated to be $21,868, or an average of $3,645 annually over the six-year period. With the project installed (1961-65) the total evaluated benefits were $109,807, or an average annual benefit of $21,961. For the evaluation period (1955-65) average flood damages prevented amounted to $11,971 annually. Obviously, the evaluation period was too short to infer that annual benefits determined for the evaluation period will be representative of future benefits.

The only major storm during the first 10 years of the evaluation period (1955-64) occurred on July 30, 1957. The storm was centered over the drainage area of structure K-79 near the head of East Kiowa Creek. Estimated benefits from this one storm amounted to $12,584 or 40 percent of all benefits during the 10-year period. The storm of June 17, 1965, was of approximately the same intensity over the K-79 drainage as the 1957 storm, but the 1965 storm produced general flooding and damage to areas that were protected in 1957. Benefits from the watershed project for the June 17, 1965, storm are discussed in detail in the next section of this report.

June 17, 1965, Storm - Damages and Benefits

The storm of June 17, 1965, produced recorded rainfall amounts ranging from 0.90 inches near Kiowa to 7.6 inches near Eastonville. Rain gage records and emergency spillway flow of floodwater-retarding structures indicate that this storm was concentrated on the headwaters of West Kiowa Creek, along the entire length of East Kiowa Creek, and along the east side of Main Kiowa Creek down to about 3 miles above Kiowa. Of 27 floodwater-retarding structures known to have emergency spillway flow, three were on the upper part of West Kiowa Creek, 19 were along East Kiowa Creek, and five were along the east side of Main Kiowa Creek.

Most of the floodwater-retarding structures withstood the flood flows with very little damage. One structure (Q-51) experienced sufficient storm damage to warrant extensive repairs. The spillway return area was badly eroded with about 2,000 cubic yards of earth washed away.

Table 21. Estimated benefits from project measures, Kiowa Creek Watershed, Colorado 1955-65 1/

Item	Project Installation Period						With Project Installed				Total
	1955	1956	1957	1958	1959	1960	1961	1963	1964	1965	
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Floodwater damage prevention											
Crop and pasture		215	2,282	20	20	60	245	1,267	180	11,937	16,226
Fences	30			60	60	60	220	320	420	5,903	7,073
Livestock								200		2,277	2,477
Buildings and machinery										1,239	1,239
Irrigation works										5,480	5,480
Other agriculture										3,914	3,914
Roads and bridges		1,000	15,196				450	3,500	500	56,364	77,010
Other non-agriculture										1,922	1,922
Subtotal	30	1,215	17,478	80	80	120	915	5,287	1,100	89,036	115,341
Sediment damage reduction	20	675	2,050	50	30	40	100	2,000	300	6,031	11,296
Erosion damage reduction (flood plain)										5,038	5,038
Total benefits 2/	50	1,890	19,528	130	110	160	1,015	7,287	1,400	100,105	131,675

1/ No flood prevention benefits were attributable to project measures in 1962.
2/ Excluding benefits from erosion damage reduction and more intensive use of flood plain land.

Erosion occurred on the spillway return areas of two other structures but repairs were not considered necessary. A scour hole below a principal spillway outlet of one structure was reshaped, and riprap added to repair damage. The Army Corps of Engineers flood dike at Elbert was damaged by floodwater to the extent that it required repair and strengthening.

As soon as possible after this storm, land areas covered by floodwaters were mapped on aerial photographs to show areas flooded, sediment damage, and streambank and gully erosion. Photographs of flood damages and project storage were taken to document the effect of project measures on this storm. In November and December 1965, all farm operators in the Kiowa Creek Watershed were interviewed to obtain estimates of floodwater and erosion damages to their farms. Supplemental information on all flood emergency repairs made with government assistance was obtained from the Elbert and El Paso County Agricultural Stabilization and Conservation Service offices. Estimates of floodwater damages to public property in the watershed were obtained from local officials.

About 2,700 acres were flooded as a result of the June 17, 1965 storm, resulting in evaluated floodwater damages of $169,165 (Table 20). Of these damages, $89,327 (53 percent) occurred along East Kiowa Creek, $17,396 (10 percent) occurred along West Kiowa Creek, and $62,442 (37 percent) occurred along the mainstem of Kiowa Creek. Two-thirds of the $29,525 crop and pasture floodwater damage was from loss of crops; one-third was attributable to reduced stands of alfalfa and other hayland. Approximately 37 miles of fence were either lost or damaged during this storm. Damages to fences were estimated at $15,557. Livestock losses amounted to 12 cows, 1 bull, 21 calves, and 4 shetland ponies, with a total estimated value of $4,740. Damage to irrigation wells, reservoirs, sprinkler irrigation pipe, and irrigation pumps and motors totaled $12,884. Damage to roads and bridges amounted to $58,366. These occurred mostly in El Paso County where damages totaled $38,669 to county maintained roads and bridges alone.

More than 300 acres of crop and pasture land suffered heavy sediment damages amounting to $16,595. The productive capacity of about 30 acres of crop and pasture land was destroyed through erosion. Streambank erosion occurred along about 50,500 lineal feet on the main channels. Evaluated erosion damage amounted to $14,659.

Hydrologic studies of the June 17, 1965 storm were made to provide the basis for evaluating benefits attributable to installed structural and land treatment measures. It is estimated that a total of 2,831 acre-feet of floodwater was detained by the floodwater-retarding structures of which 1,066 acre-feet were detained by structures in the East Kiowa Creek Watershed, 681 acre-feet by structures in the West Kiowa Creek Watershed and 1,084 acre-feet by structures along the east side of Main Kiowa. This structural detention volume plus the effect of the land treatment program is estimated to have reduced the peak discharge on West Kiowa Creek by 6,000 cfs, on East Kiowa Creek by 11,500 cfs, and on Kiowa Creek at Kiowa by 12,300 cfs.

These peak discharge relationships were used as the basis for all floodwater damage reduction benefit evaluations. Since road and bridge damage is frequently related to debris or other special factors, road and bridge damages were estimated by individual crossings.

Without the project, damages from the storm of June 17, 1965, would have amounted to an estimated $269,270 (Table 22). Actual damage experienced from this storm amounted to $169,165. Thus, project benefits are estimated at $100,105. The project prevented only a little over one-third of the potential damage from this storm.

Table 22. Estimated flood damage reduction benefits from the storm of June 17, 1965, Kiowa Creek Watershed, Colorado

Item	Estimated Damage		Damage Reduction Benefit	
	Without Project	With Project		
	Dollars	Dollars	Dollars	Percent
Floodwater damage				
Crop and pasture	41,462	29,525	11,937	28.8
Fences	21,460	15,557	5,903	27.5
Livestock	7,017	4,740	2,277	32.4
Buildings and machinery	4,255	3,016	1,239	29.1
Irrigation works	18,364	12,884	5,480	29.8
Other agriculture	13,637	9,723	3,914	28.7
Roads and bridges	114,730	58,366	56,364	49.1
Other non-agriculture	6,022	4,100	1,922	31.9
Subtotal	226,947	137,911	89,036	39.2
Sediment damage	22,626	16,595	6,031	26.7
Erosion damage	19,697	14,659	5,038	25.6
Total	269,270	169,165	100,105	37.2

The largest single benefit was the $56,364 reduction in road and bridge damage. There is some question as to the ability of the bridge at Kiowa to withstand the 32,000 cfs peak discharge estimated for without project conditions. Had the bridge been destroyed, flood losses would have been $150,000, or $120,000 greater than the estimate used for evaluation purposes.

Of the total damage reduction benefits, 15 percent were on West Kiowa Creek, 25 percent for East Kiowa, and 60 percent were on Main Kiowa Creek. Benefits on the Main Kiowa Creek are primarily a result of estimated damage reduction to roads and bridges of $32,600.

The land treatment (B Measures) program, installed as part of the project, was estimated to have provided flood damage reduction benefits of $13,900, or 14 percent of all benefits. This estimate does not include benefits from sediment and erosion damage reduction in the upland areas of the watershed, or from reduction of sediment deposition in the floodwater-retarding structures. Sediment deposition was less than could be expected from a storm of this intensity and these benefits are believed to have been substantial.

During the survey, 82 farm operators were asked if they thought the watershed project had reduced damages caused by the June 1965 storm. Forty-four percent thought it had, 32 percent thought it had not, and 24 percent said they did not know or that it had not benefited their farm. The opinion was generally expressed that more dams were needed and that they should be larger, particularly in areas noted for heavy rainfall. This opinion is borne out by the small percentage of damage reduction by the floodwater-retarding structures in the storm of June 17, 1965.

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